UNITED STATES
CONSUMER PRODUCT SAFETY COMMISSION
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Memorandum

Date: JUN 25 2001

TO : The Commission
Todd A. Stevenson, Acting Secretary

THROUGH: Michael S. Solender, General Counsel MY TM
Thomas W. Murr, Jr., Acting Executive Director

FROM : Ronald L. Medford, Assistant Executive Director, RLM
Office of Hazard Identification and Reduction
Andrew M. Trotta, Electrical Engineer, Division of Electrical Engineering AMT

SUBJECT : Contractor Report on the Feasibility of Modifying Range Designs to Address Cooking Fires

This memorandum transmits a contractor report on a study of the technical, practical, and manufacturing feasibility of technologies to address rangetop cooking fires (Tab A). The objective of the study was to identify available technologies, including the experimental work performed and contracted by the U.S. Consumer Product Safety Commission (CPSC), and assess the feasibility of incorporating a technology into a range to reduce the risk of cooking fires. Each year cooking fires from pan material ignitions cause an estimated 47,200 residential structure fires, claiming 80 lives, injuring 2,440 victims and resulting in $134.6 million in property loss.

This report was completed by Arthur D. Little, Inc. (ADL) in support of CPSC work to address residential cooking fires.[1]

Because of the large number of prospective concepts and the similarities in principle and operation of many, the technologies were classified into groups and then screened to identify the most viable concepts. A detailed analysis of the most promising technology classes was performed to assess their ability to reduce the risk of cooking fires, to minimize impact on cooking performance, and to be implemented into a range.

The ADL staff catalogued 111 technologies from various sources including patents, technical literature, conference proceedings, product brochures, and the Internet. Of these 111 concepts, 29 were eliminated from additional consideration because the technology increased a

[1] The scope of the study was augmented by additional tasks that the Association of Home Appliance Manufacturers (AHAM) funded through a wholly-owned subsidiary, the Appliance Research Consortium (ARC). This additional funding was provided under a separate contract from ARC and included payment for ADL staff to consider fire extinguishment technologies in their assessment and to visit range manufacturers' factories and engineering development sites as part of its information gathering effort. CPSC staff accompanied ADL on the visits to the manufacturers' facilities.

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safety risk to the user, did not address a critical aspect of the surface cooking fire issue, did not have enough supporting documentation, or was impractical for residential use. To simplify the analysis, the remaining concepts were then divided into 22 classes according to function.

With guidance from range manufacturers and CPSC staff, ADL developed a list of screening criteria to select the most promising technology classes. The selection criteria were based on two primary considerations: (1) impact of the technology on cooking performance, operability, reliability/durability, safety, manufacturability/installation/service of the cooktop, and (2) effectiveness of the technology to mitigate surface cooking fires. After the screening process, seven technology classes were assessed in more detail.

The results are summarized below in four categories:

I. **DETECT AND EXTINGUISH FIRE**

-- <u>Fusible Link for Fire Detection</u>

-- <u>Non-optical Temperature Sensor for Fire Detection</u>.

These concepts use a mechanical or electronic sensor to detect a fire through a rise in temperature, then actuate a mechanism to release a fire-extinguishing agent. The technology is currently available as a fire protection device to install in a residential kitchen and would require some modification of range designs to integrate the system into the range. A fail-safe capability to insure that the range could not be used in the event that the system is not operational requires development. Extinguisher cylinders need to be tested/recharged every 12 years. These systems would address any cooktop fire that exceeded the sensor temperature threshold. The cooking process would be unaffected by these systems, but activation of the system would prohibit cooking until after the extinguishing agent has been removed from the range surface. The primary implementation issue is that residential kitchen extinguishment systems are manufactured by the fire extinguishing industry at the rate of tens of thousands of units annually as opposed to millions of ranges produced annually by appliance manufacturers.

II. **PREVENT UNATTENDED COOKING - WARNING AND CONTROL**

-- <u>Motion Sensor Only</u>

-- <u>Motion and Power Level Sensor</u>

-- <u>Power Level Sensors and Timers</u>

These concepts use various techniques such as a motion detector or a timer to require that a cook be present to allow the cooking process to continue. Absence of the cook beyond the preset time limit would cause the burners to shut down. A power level sensor would allow unattended cooking for lower burner settings. The effectiveness of these systems in reducing fire risk is directly related to the assumption that the presence of the cook would eliminate a majority of cooking fires. The technology is in early stages of development but appears to be feasible; component reliability and durability is unknown. Range designs would require modification to implement the appropriate sensors and controls. Although most cooking functions would not be affected, consumer interface with the range could be dramatically affected by requiring attendance to the range. Therefore, the primary concern with this approach is the practicality of not being able to be more than a short distance away from the range (about 1 foot) before it shuts off. This is not likely to be acceptable to consumers.

III. PREVENT UNATTENDED COOKING - WARNING ONLY -- MOTION SENSOR

These concepts are basically the same as the Prevent Unattended Cooking - Warning and Control technologies, but an alarm will sound only when the motion sensor detects that the cook has been away "too long." The implementation issues are the same; the effectiveness relies solely on the attentiveness of the consumer.

IV. PREVENT FOOD IGNITION IN PAN -- ELECTRONIC SIGNAL PROCESSING - TEMPERATURE SENSOR CONTACTS POT

This is the approach that CPSC staff has been studying. This concept relies on measuring pan temperature and limiting the burner output to keep the pan contents below the ignition point of common cooking materials. Testing of this concept by CPSC, the National Institute of Standards and Technology, the Good Housekeeping Institute, Energy International, and ADL indicates that there is a considerable margin between pan temperatures required for cooking and the pan temperature for ignition of cooking oils. The fundamental technical issue is developing a sensor that measures pan temperature accurately and reliably. Although several Japanese manufacturers produce gas cooktops that have temperature control systems to prevent ignition of tempura oil, according to ADL, they do not currently meet the reliability and durability requirements of U.S. range manufacturers. ADL estimates that pan contact temperature sensor development would require 2 to 3 years of extensive research to provide the level of durability and reliability needed. With a suitable pan temperature sensor, cooking performance should be unaffected. These systems should mitigate cooking fires caused by ignition of cooking materials in a pan. This technology could not be applied to glass cooktops because the pan contact sensor would require a penetration through the glass.

The CPSC staff is engaged in efforts to upgrade voluntary standards for both gas and electric ranges to include requirements to address ignition of cooking materials on the cooktop. The attached ADL study illustrates that there are several methods that could be used to modify ranges to prevent fires caused by ignition of cooking materials.

The results of the ADL study were presented at a meeting of the Standards Technical Panel for Household Electric Ranges (UL 858) at Underwriters Laboratories in Northbrook, IL on May 15, 2001. CPSC staff believes that the information in the report supports the concept that the staff has been developing. The CPSC staff considers the best approach to be prevention of unwanted ignitions. If new alternatives to ignition prevention systems are developed, such as systems that extinguish range fires, the CPSC staff believes that such a system should be integral to the range to ensure protection with any installation. The staff will be participating in the gas and electric range standards development process and will evaluate the progress and commitment of the manufacturers to support the development of voluntary requirements to address this issue.

Attachment

TAB A

Arthur D Little

Arthur D Little

Technical, Practical and Manufacturing Feasibility of Technologies to Address Surface Cooking Fires

Final Report

Report to:

United States Consumer Product Safety Commission

May 22, 2001

Arthur D. Little, Inc.
Acorn Park
Cambridge, Massachusetts
02140-2390

Reference 72931

ACKNOWLEDGEMENT

We would like to thank the Association of Home Appliance Manufacturers who have supported the expanded scope of this report with funding from their wholly owned subsidiary, the Appliance Research Consortium (ARC). By facilitating meetings with their member companies, AHAM provided Arthur D. Little and the CPSC access to information on technologies, products, industry issues, and perspectives relevant to the surface cooking fires program.

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1. Background

Work has been sponsored over the past six years by the Consumer Product Safety Commission (CPSC) to study and develop technology to lessen the risk of surface cooking fires. In the early phases of this work, the CPSC used the resources of the National Institute of Standards and Technology (NIST) to determine if there were a common, measurable, pre-ignition indicator for the combustion of cooking materials on a range top. From this work, the most consistent, measurable, pre-ignition indicator was concluded to be pan temperature. Follow-on phases to this work led to the design and early development of a thermocouple-based control system to limit pot temperature to a level safely below a threshold, pre-ignition condition.

Separately, other technologies have been developed to address surface cooking fires. For example, a variety of US companies offer automatic fire extinguishing systems for residential cooking applications. In addition, gas-fired cooktops are made and sold in Japan that offer a temperature control function that will modulate or shut-off to prevent overcooking, burning and overheating of deep frying oil. Other technologies have been developed that were not intended to address surface cooking fires, but are intended to monitor and control pot temperature. For example, a European appliance manufacturer offers a cooking control system that remotely monitors pot temperature with an infra red sensor and controls the heat input rate accordingly. The patent literature is full of systems, approaches, technologies and concepts to address cooking fires.

US appliance manufacturers are deeply concerned about a) the potential effectiveness of these types of technologies to reduce the incidence of cooking fires and b) the potential impact of these technologies on the cooking performance, operability, reliability, durability, safety, and manufacturability of cooking products. Reliability is a significant issue to the industry. It includes the requirement that a safety device would address all fire incidents that it was intended to address throughout the life of the appliance. In all cases, the system would need to "fail-safe", in that the range would need to shut down in case the fire safety device were not working properly.

The CPSC requested the assistance of Arthur D. Little to conduct a study to evaluate the technical, practical and manufacturing feasibility of range modifications intended to address the ignition of cooking materials. The Association of Home Appliance Manufacturers provided additional support to expand this study to include technological solutions beyond the rangetop, such as fire suppression systems, to address the broad spectrum of surface cooking fires.

To focus the scope of this study, only surface cooking fires and surface cooking fire mitigation technologies were considered. Surface cooking fires include the ignition and combustion of materials on cooktops or rangetops. These materials are primarily cooking materials, but can be paper, trash, cabinetry, fuel, accelerants or unclassified items. The 1996 report entitled *Ten Community Study of the Behaviors and Profiles of People Involved in Residential Cooking Fires* (written by the Cooking Fires Task Force of the National Association of State Fire Marshals (NASFM) and AHAM member companies) concluded that behaviors associated with range-top cooking must be given special emphasis. The statistics compiled by the Fire Analysis and Research Division of the

National Fire Protection Agency mirror the results of the NASFM. The April 2000, NFPA report entitled *US Home Cooking Fire Patterns and Trends*, stated that 73% of home cooking fires originated from surface cooking. Therefore, we reviewed fire mitigation (or management) technologies that are intended to address surface cooking fires, independent of the origin of these fires. In addition, the statistics indicate that a significant number of fires are associated with unattended cooking fires, and the ignition of cooking materials. Therefore, we also reviewed technologies that specifically target unattended cooking and the ignition of cooking materials.

2. Objective

The objective of this study is to evaluate the technical, practical and manufacturing feasibility of technologies to address surface cooking fires. Specifically, feasibility is established by evaluating the potential for the technology to be designed in such a way as to 1) be effective in mitigating surface cooking fires; and 2) meet industry standards for: reliability, durability, cooking performance, safety, operability, and manufacturability.

3. Approach

The program involved three major activities (collect information, conduct evaluation, prepare report) that were further divided into the following seven specific tasks.

3.1 Identify Patents, Products, Technologies, Systems, and Concepts

We cast a broad net to identify the products, technologies, systems and concepts that have the potential to address surface cooking fires. Some of these technologies were available in the public domain, from the patent database, web-sites, technical literature, conference proceedings, and product brochures. In addition, we followed the 'inventor trail' from CPSC meeting and phone logs, AHAM files, Arthur D. Little files, and meetings with appliance manufacturers. Some concepts, particularly as they related to combinations of sensor technologies in control systems, were proposed at Arthur D. Little as part of the searching and technology classification process.

3.2 Structure Patents, Products into Technology Classes

In order to evaluate the feasibility of fire mitigation approaches, we structured the patents, products, concepts, technologies and systems into 22 technology classes. Both CPSC and AHAM reviewed these technology classes prior to our initiating the evaluation work. A number of the products, systems, or concepts that were grouped into these technology categories constituted a 'complete' approach to address surface cooking fires. Other patents or technologies could potentially be part of an approach that would address surface cooking fires, for example, a sensor technology, or an extinguishing agent, or a contact temperature sensor. In some technology classes, we grouped many products, patents and ancillary technologies. Other technology classes contained only one patent or one concept.

3.3 Identify, Review, and Develop Data to Support Technology Evaluation

We identified, reviewed, and developed data to support the technology evaluation process. We reviewed a large amount of literature, including:

- the reports covering the cooking fires work sponsored by the CPSC;
- the analyses conducted by the AHAM Cooking Fires Working Group and the memorandums covering the minutes of their meetings;
- fire statistics generated by the National Fire Protection Association (NFPA) and National Fire Incident Reporting System (NFIRS) and summarized by NFPA;
- studies conducted by the National Association of State Fire Marshals Cooking Task Force;
- AMCE Conference Proceedings;
- IEEE transactions;
- data on edible oils from a variety of sources.

- AHAM test reports covering work conducted as part of the 1986 Food Fire Test Program.

In addition, we reviewed videos illustrating grease fires and safe cooking techniques that AHAM made available to us.

To deepen our understanding of industry issues and concerns, we met with appliance manufacturers to discuss their product lines, product development process, technology needs, technology evaluations, relevant tests, concepts, related product development programs, product trends, industry concerns, and safety requirements. The specific elements of the discussions at these meetings are confidential, (as per our agreement with AHAM and CPSC) but we have incorporated the general information into our evaluations.

In addition to the literature reviews and meetings, we conducted some tests in our lab to obtain additional data on system performance and characteristics. We obtained the CPSC range prototypes and conducted limited testing on both the gas and electric units. We reviewed the Good Housekeeping report covering their tests of these units. We obtained a Rinnai Gas Table with a temperature controller and conducted numerous tests to understand its operation and performance. To supplement these tests, we reviewed the Rinnai User Manual, translated from Japanese by AHAM.

Finally, we utilized our understanding of the appliance industry, the standards process, the science of cooking products, and the product development process to support our analyses and evaluation work.

3.4 Develop Evaluation Criteria

Specific evaluation criteria and metrics were developed in the categories of cooking performance, operability, reliability/durability, manufacturability/installation/service, safety, and effectiveness in addressing surface cooking fires. These criteria and metrics were reviewed with representatives from CPSC and AHAM. It was agreed that as a starting point for the screening work, each criteria would have equal weighting relative to each other. These criteria were further grouped into two categories: 1) criteria that reflected the effectiveness of the technology to mitigate surface cooking fires and 2) criteria that reflected the potentially negative impact of the technology on the performance, operation reliability safety of the cooking system.

3.5 Screen Technology Classes by Evaluation Criteria

As an initial screen, we evaluated each technology class with respect to the agreed upon evaluation criteria and metrics. The evaluation scores for each technology class were tallied. A scatter plot of fire mitigation effectiveness versus impact on product value was generated for the set of technologies. Two additional 'technology classes' were evaluated as a process check: 'do nothing' (i.e. make no change to range/add no fire suppression technology), and 'add smoke alarm only'.

Technologies that had comparatively low effectiveness or excessive negative impact on product value were eliminated from more detailed evaluation.

3.6 Select Technology Classes for Detailed Evaluation

The remaining technologies were screened for the potential to improve their effectiveness or decrease their impact on product value. Some technologies had inherent limitations. Others were found to have limitations in their current implementation, but had potential to be improved with additional research and development, or with the application of other known technologies. We selected 7 technologies for detailed evaluation.

3.7 Evaluate Selected Technology Classes

We collected additional information on the 7 technologies selected for evaluation. This activity included interviews with vendors, additional laboratory tests, and discussions with Arthur D. Little staff with relevant technology and/or industry experience. A draft report was prepared for review and comment by CPSC and AHAM representatives.

4. Results

4.1 Patents, Products, Technologies, Systems, Concepts

A complete list of the patents, products, technologies, systems, and concepts that we have identified that could potentially address surface cooking fires (or be part of a system to address surface cooking fires) is in Appendix A.

A number of these technologies were eliminated from additional consideration due to one or more of the following reasons:

- The technology had the potential to increase a safety risk to the homeowner (e.g. it required the user to extinguish the flame manually, or it required the homeowner to move closer to the flames in some way),
- The technology did not address a critical aspect of the surface cooking fire issue (e.g. it was not appropriate for grease fires of any kind)
- We were unsuccessful in obtaining additional information about the technology. (e.g. we some information on a web site, but received no response to phone calls, e-mails etc. for additional information)
- The technology or approach was obviously impractical or not feasible for residential application.

A list of the technologies that were eliminated from additional consideration (and the reasons for doing so) is included in Appendix B.

The remaining technologies were clustered into technology classes so that they could be more effectively evaluated. These classes are described in the following section.

4.2 Technology Classes

Table 4-1 lists the technology classes that we used to organize the hundreds of patents, products, technologies, systems and concepts identified in the first task.

Table 4-1 Fire Mitigation Technology Classes

Detect and Extinguish Fire
- Fusible Parts
- Non-optical Temperature Sensor
- Optical Temperature Sensor
- Smoke & Temperature Sensor

Detect a Fire – Provide Warning only
- Non-optical Temperature Sensor
- Optical T Sensor
- Smoke Sensor

Contain or Manage Fire
- Passive
- Active

Prevent Unattended Cooking- Warning and Control
- Motion Sensor Only
- Motion Sensor and Power level
- Motion Sensor and Temperature sensor
- Power level Sensor and Timer

Prevent Unattended Cooking- Warning Only
- Motion Sensor Only
- Motion Sensor and Power Level
- Power Level sensor and Timer

Prevent Food Ignition in Pan
- Electronic Signal Processing, Mode Selection, Pan-contact Temperature Sensor
- Electronic Signal Processing, Mode Selection, Non-contact Temperature Sensor
- Electronic Signal Processing, Auto-Control to Temperature Threshold, Pan-contact Temperature Sensor
- Electronic Signal Processing, Auto-Control to Temperature Threshold, Non-contact Temperature Sensor
- No Signal Processing, Mechanical Actuation

Boil Dry/Spill-over Sensor and Control

Each technology class is described and illustrated below.

Detect/Extinguish Fire -- Fusible Parts (Tech Class 1)

The first four technology classes involve detecting the presence of a fire and activating a fire extinguishing system. In the category of *Detect/Extinguish Fire – Fusible Parts*, the fire extinguishing technology is activated by a fusible link located above or near the cooktop that melts in response to a cooking fire. This system would respond to a surface cooking fire of any origin. When the fusible part melts due to the heat generated from the cooking fire, it triggers the release of fire extinguishing material onto the cooktop. This trigger can be mechanical or electrical. The fire extinguishing material can be liquid (generally a potassium-based, wet chemical formulated to extinguish grease fires) or powder (bicarbonate of soda or other dry mixture). The system can include the actuation of an alarm and/or heat source cut-off (either gas or electric power).

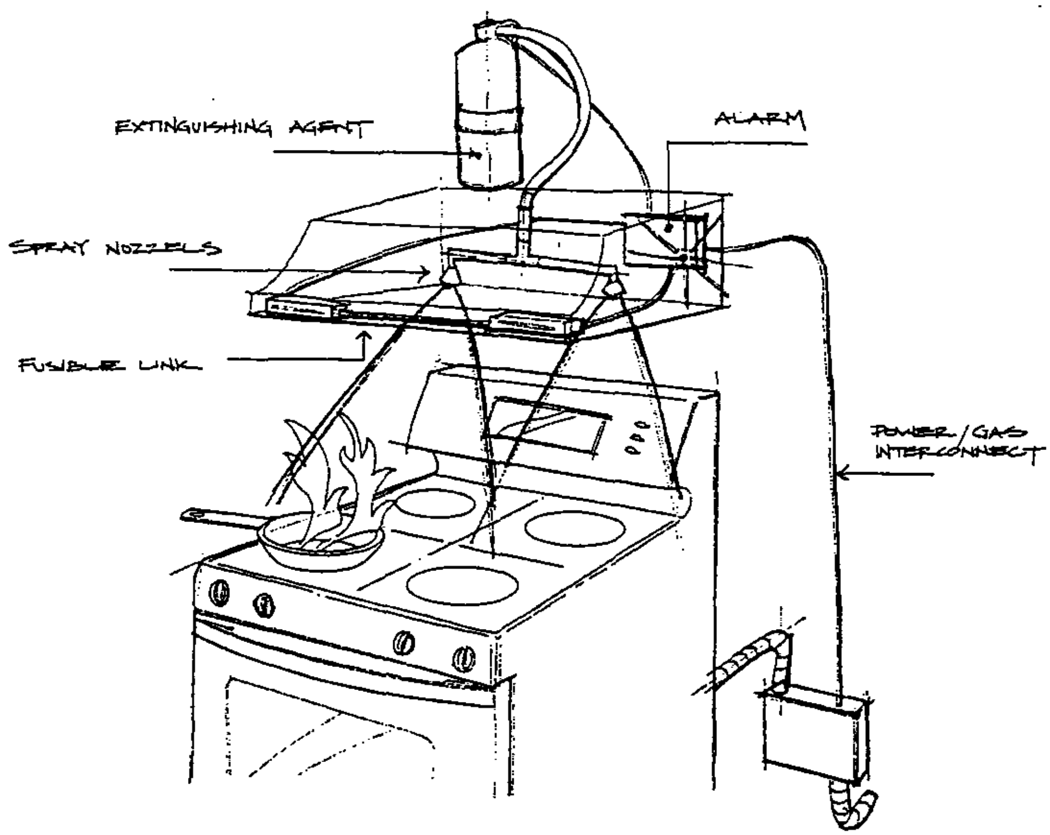


Figure 4-1: Detect/Extinguish Fire – Fusible Parts

Detect/Extinguish Fire -- Non-optical Temperature Sensor (Tech Class 2)

This category differs from the one described above in the way the fire is detected. Instead of a fusible material, this technology utilizes a non-optical temperature sensor, such as a thermocouple, diode or thermistor, located near the cooktop (usually in hood) to detect fire. When the sensor response exceeds a threshold temperature, a release mechanism for the fire-extinguishing agent is actuated. As with the system described previously, a heat source cut-off mechanism or an alarm can be included in the system.

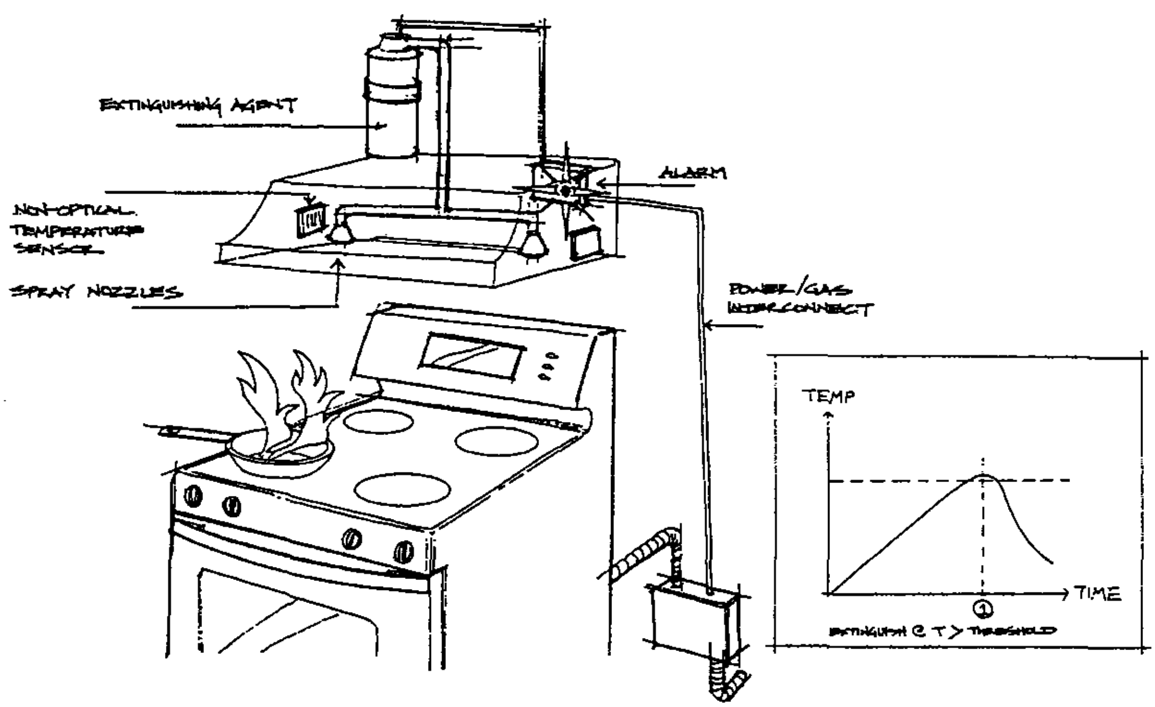


Figure 4-2: Detect/Extinguish Fire -- Non-optical T sensor

Detect/Extinguish Fire -- Optical Temperature Sensor (Tech Class 3)

In this fire extinguishing technology, an optical temperature sensor, such as an infra red (IR) sensor, is used to monitor the temperature surrounding or on top of the cooktop. When a temperature is sensed that exceeds a threshold, an alarm is sounded. At the same time, the system will actuate the release of the fire-extinguishing agent and can also turn off the cooktop heat source.

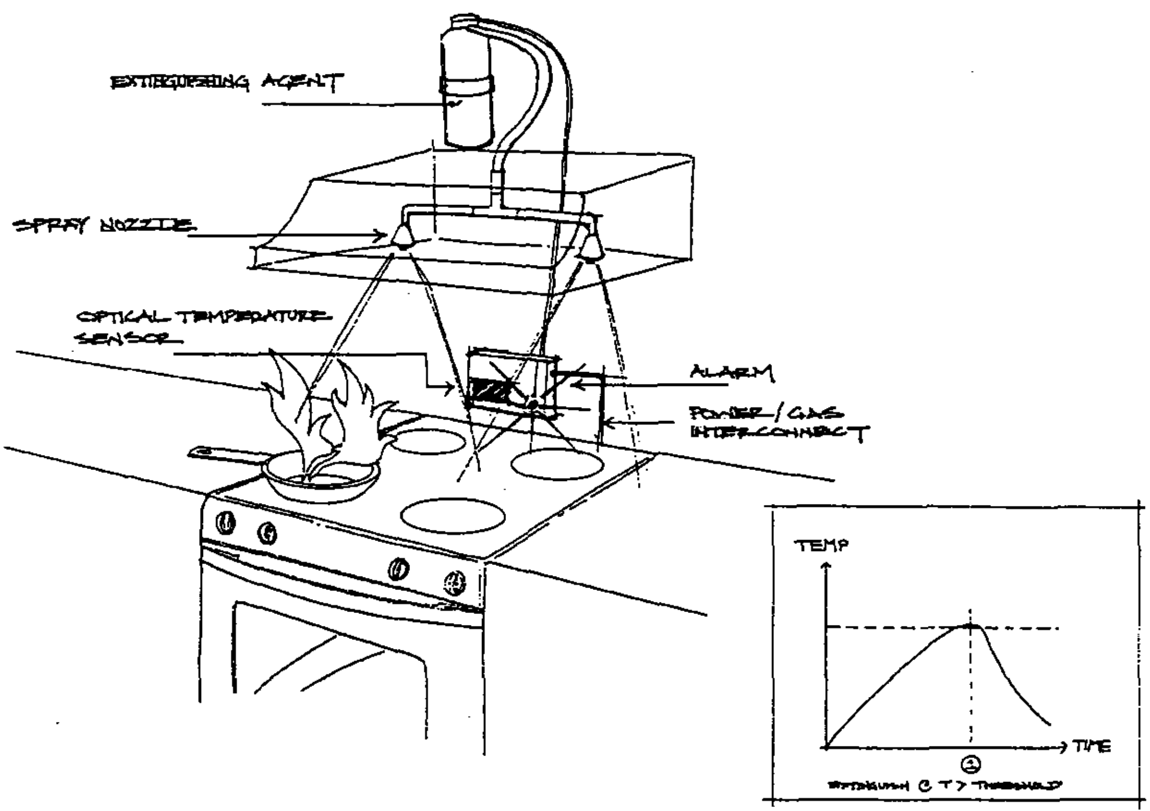


Figure 4-3: Detect/Extinguish Fire – Optical T sensor

Detect/Extinguish Fire -- Smoke + Temperature Sensor (Tech Class 4)

This fire extinguishing system utilizes the combination of both smoke and temperature sensors to determine the presence of a surface cooking fire. First, the smoke sensor will detect a significant amount of smoke and sound the alarm. When the smoke is accompanied by a temperature exceeding a threshold level at the area surrounding the cooktop, it will turn off the heat source and either release fire extinguisher material and/or contact outside services (911 or fire department).

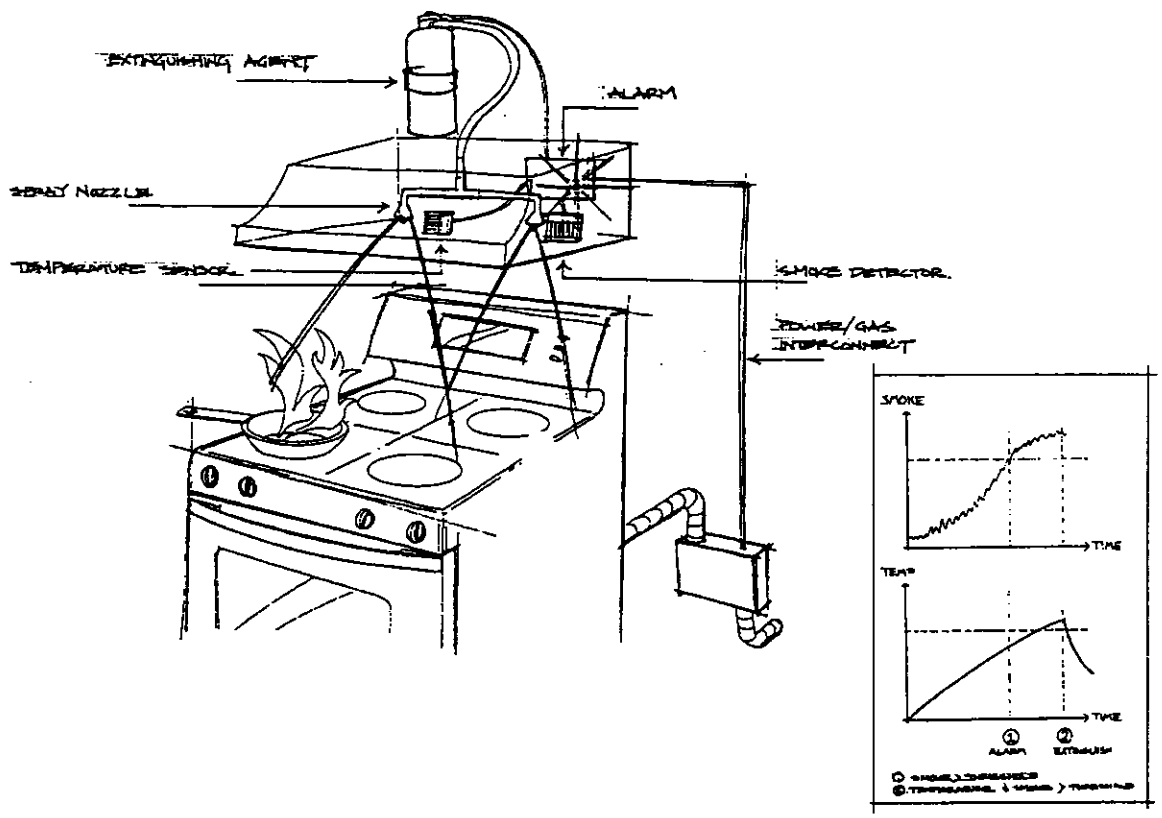


Figure 4-4: Detect/Extinguish Fire – Smoke + T sensor

Detect Fire - Warning Only -- Non-optical Temperature Sensor (Tech Class 5)

This technology warns of the presence of fire, but does not actuate a fire extinguishing system. The presence of a fire is detected by a non-optical temperature sensor, such as a thermocouple, diode, or thermistor, located near the cooktop (usually in hood) to detect fire. When a threshold temperature is exceeded, an alarm will warn the user of a fire.

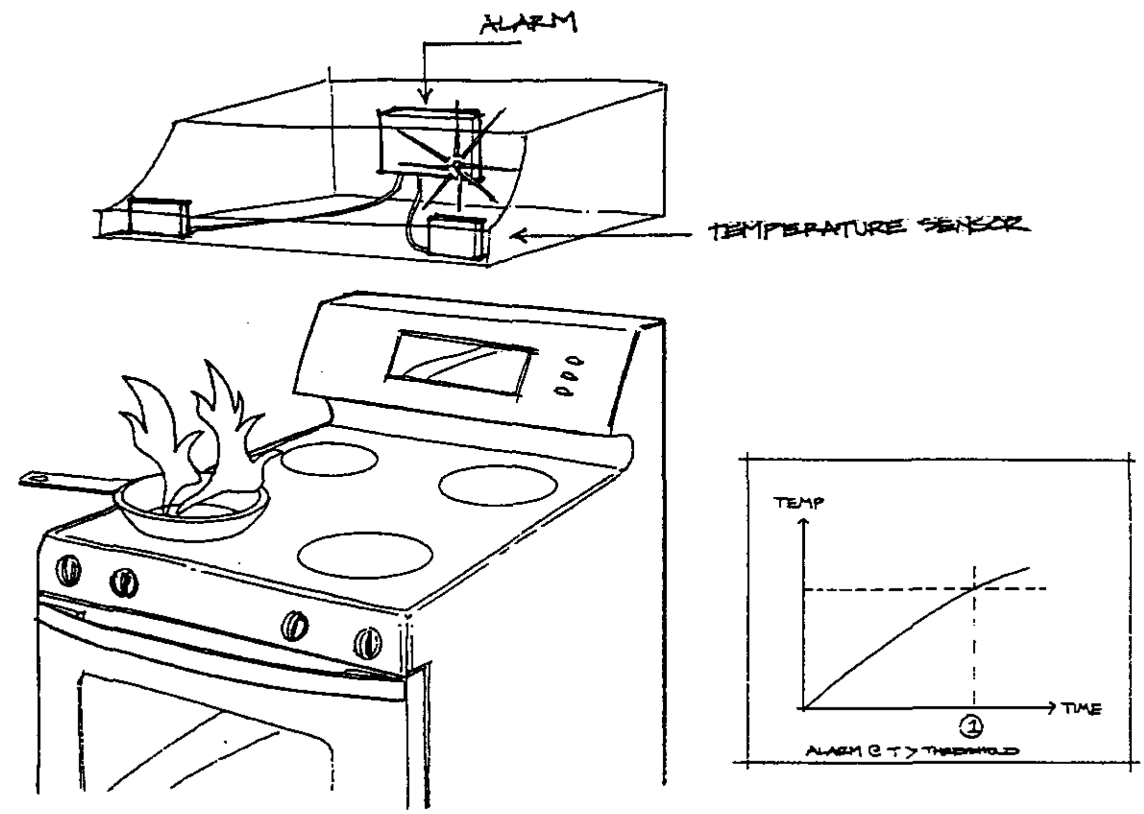


Figure 4-5: Detect Fire - Warning Only -- Non-optical T sensor

Detect Fire - Warning Only -- Optical Temperature Sensor (Tech Class 6)

Again, as with Technology Class 5, this is a warning system without a fire extinguishing system. In this case, an optical temperature sensor, such as and infra-red (IR) sensor, is used to monitor the temperature surrounding or on top of the cooktop. When the temperature exceeds a threshold, an alarm is actuated.

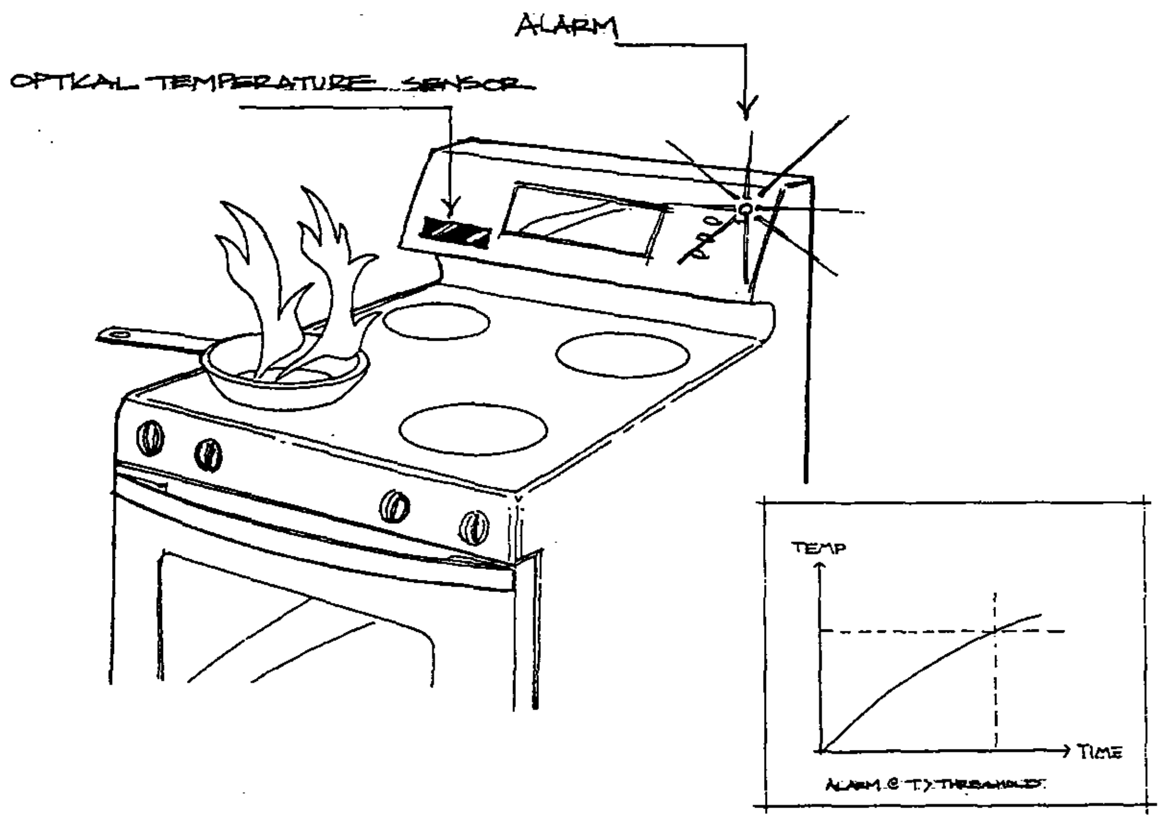


Figure 4-6: Detect Fire - Warning Only -- Optical T sensor

Detect Fire - Warning Only -- Smoke Sensor (Tech Class 7)

In this fire warning system, a smoke sensor located near the cooktop can detect the on-set of certain cooking fires, particularly those involving oil, grease, or fat that generate large amounts of smoke prior to igniting. The smoke sensor triggers an alarm when smoke levels exceed a threshold level.

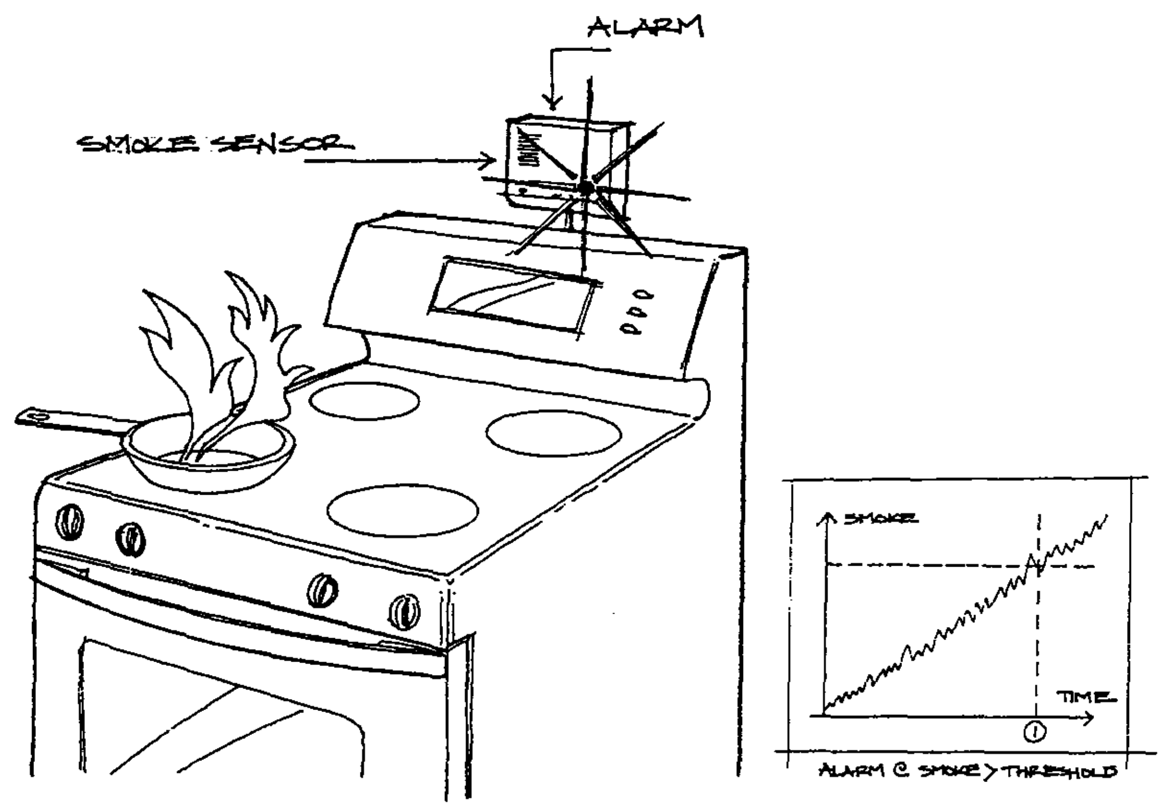


Figure 4-7: Detect Fire - Warning Only – Smoke Sensor

Contain/Manage Fire Passive (Tech Class 8)

Three fire resistant panels are permanently attached to the sides and back of the cooktop. The panels are intended to contain a fire from spreading to any walls surrounding the cooktop or any flammable products or materials stored nearby the cooktop.

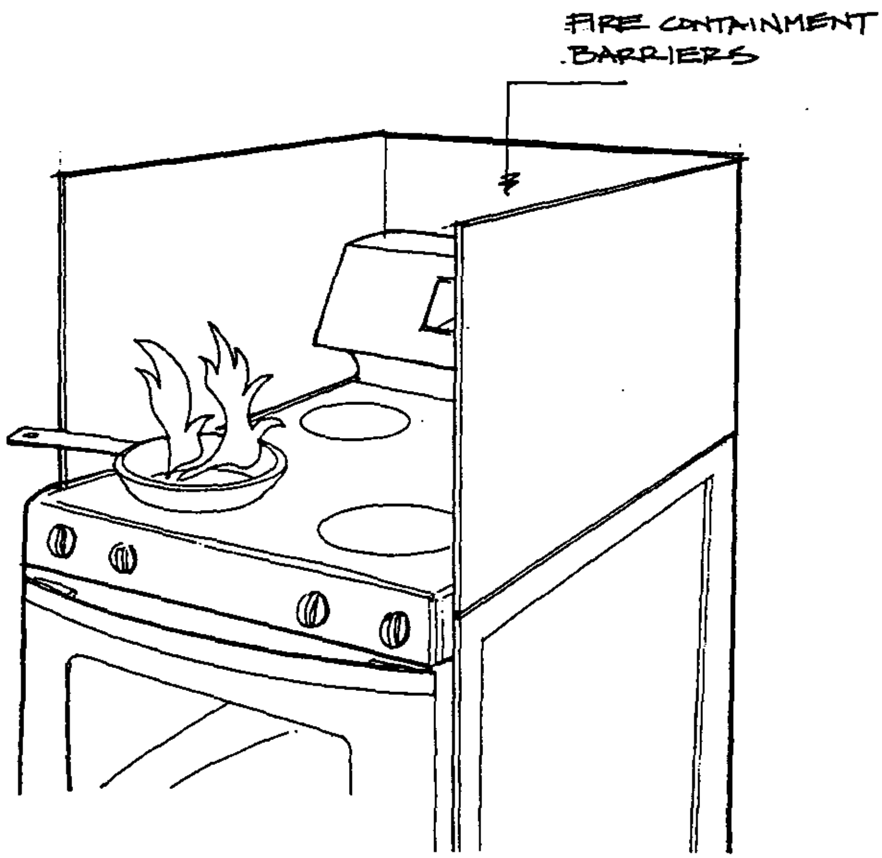


Figure 4-8: Contain/Manage Fire Passive

Contain/Manage Fire Active (Tech Class 9)

This concept defines an active system that completely surrounds the cooktop in case of fire. The system is activated when the temperature above the cooktop is higher than a threshold level. In one configuration, the fire resistant enclosure is in the form of a hood that drops to the cooking surface to contain the fire. A provision to turn off the heat source is also possible.

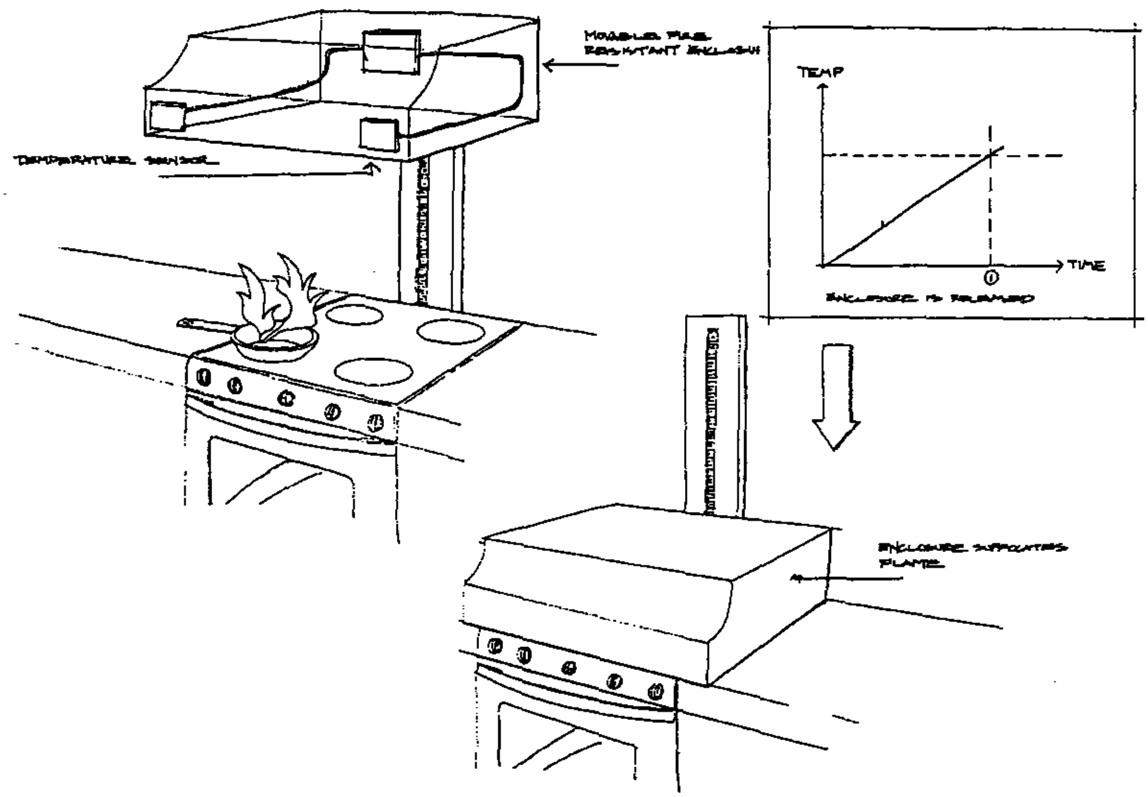


Figure 4-9: Contain/Manage Fire Active

Prevent Unattended Cooking -- Warning and Control -- Motion Sensor Only (Tech Class 10)

This technology is intended to require that a person be present while the cooktop is being used. This approach uses a motion sensor to detect the presence of a user near the cooktop. There are various possible locations for motion sensor, but many patents reference the sensor on the front panel of the cooktop. Slightly different types of algorithms are applied but in general, the system sounds an alarm if no person is detected near the cooktop after a set amount of time. The cook can return to the stove and reset the system without any effect on the cooking process. However, if no one responds to the warning alarm, the control will adjust the hob accordingly: e.g. reduce it or turn it off.

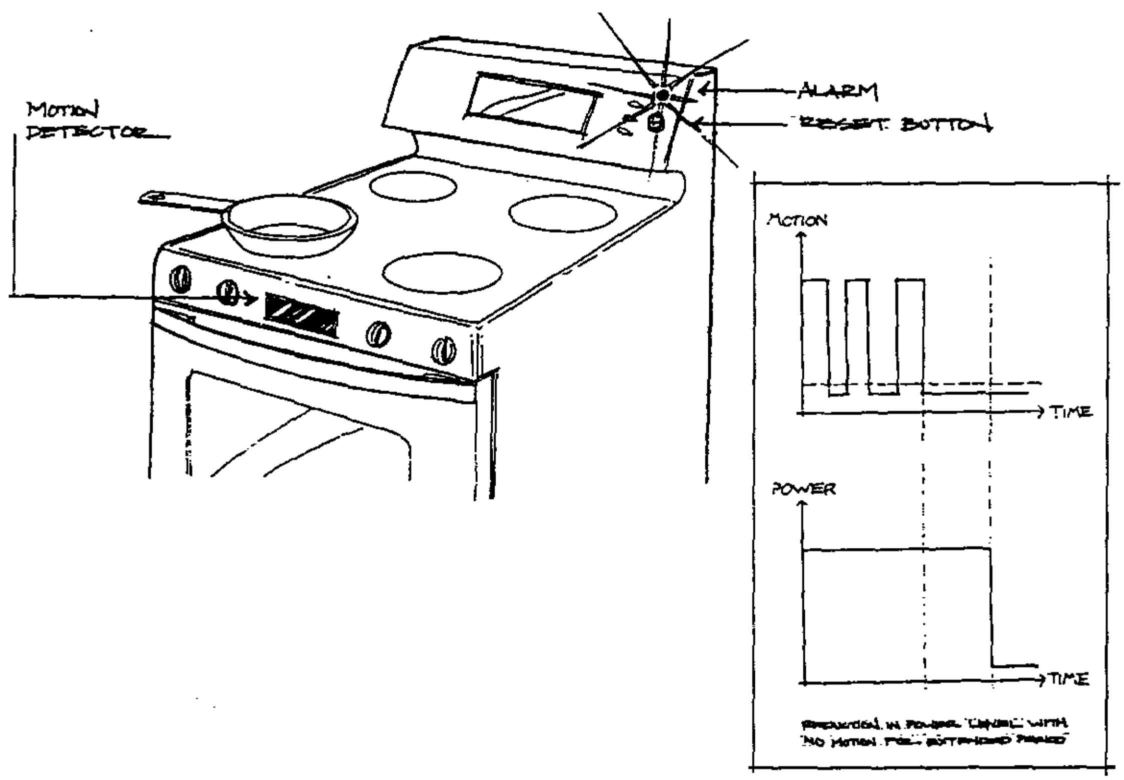


Figure 4-10: Prevent Unattended Cooking – Warning and Control – Motion sensor only

Prevent Unattended Cooking -- Warning and Control -- Motion + T Sensor (Tech Class 11)

Again, this technology is intended to require that a person attend to the cooking process. However, this technology couples a motion detector with a temperature sensor so that the person is not required to be present unless the pan temperature is nearing a potentially pre-ignition condition. A pan-contact temperature sensor monitors the temperature of the pan. When the pan-bottom temperature exceeds a threshold limit, the controller will decrease the heat input unless the motion detector senses the presence of the cook near the cooktop. If a person is detected, system might give a warning alarm to alert of the cook of a possible near fire condition.

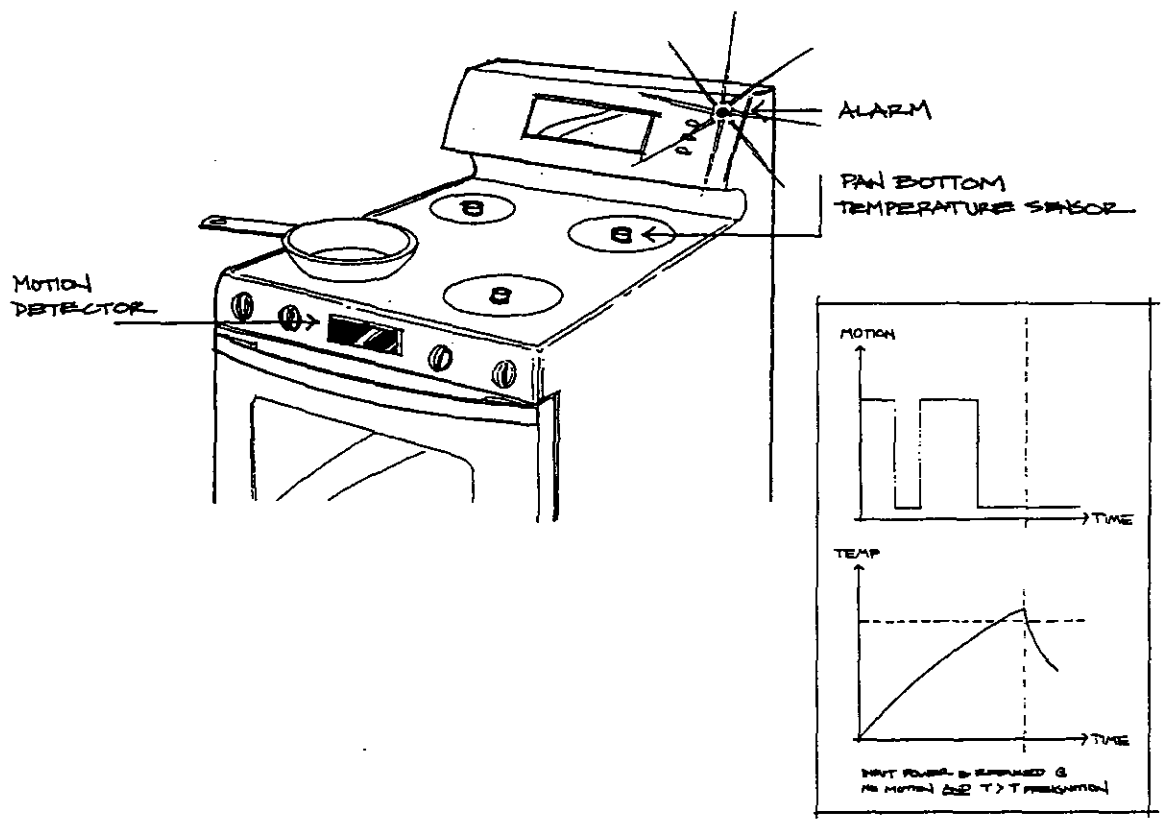


Figure 4-11: Prevent Unattended Cooking -- Warning and Control -- Motion + T sensor

Prevent Unattended Cooking -- Warning and Control -- Motion + Power Sensor (Tech Class 12)

This approach to prevent unattended cooking actuates only when the power level of the heat source surpasses a pre-set level (e.g. Medium-High). When the system actuates, the motion sensor monitors the presence of a user near the cooktop. When no user is detected after a pre-set duration, the alarm is sounded. If there is no response to the alarm (e.g. the user activates a re-set button) the controller will reduce the heat input to the burner or element.

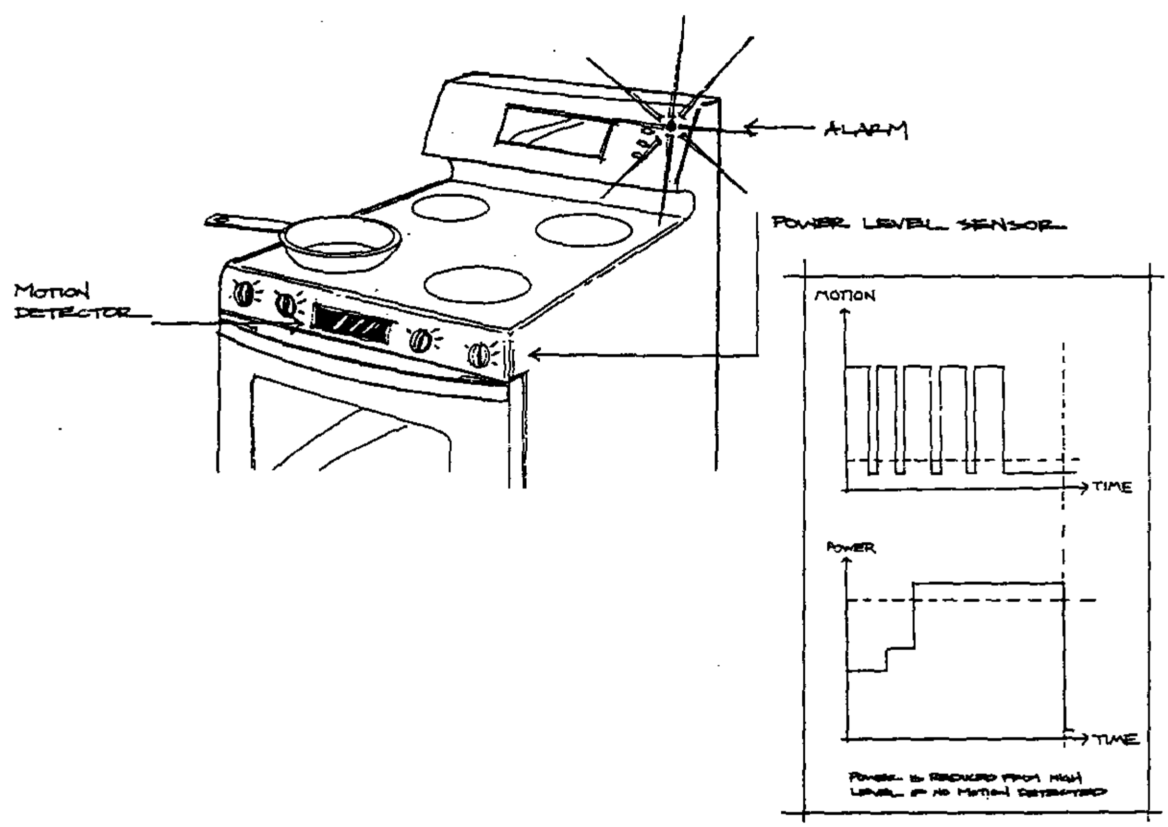


Figure 4-12: Prevent Unattended Cooking – Warning and Control – Motion + Power sensor

Prevent Unattended Cooking -- Warning and Control -- Power Level Sensor + Timer (Tech Class 13)

This approach to prevent unattended cooking has no motion detector. Instead, an alarm and control will activate based on the power level selected and a timer that is a function of the power level. Specifically, a time interval is associated with the power level of the element or burner (this could be implemented with relays, and may not require an electronic micro-controller). A timer will trigger an alarm to sound after the element or burner has been turned on. The user would press a re-set button to establish user presence near the cooktop. If the re-set button were not pushed, the control would turn off power to the element or gas to the burner. There are numerous possible variations of this approach. In one configuration, the control and alarm system actuates only above a minimum power level (i.e. activates only when element or burner is set higher than 'medium-low').

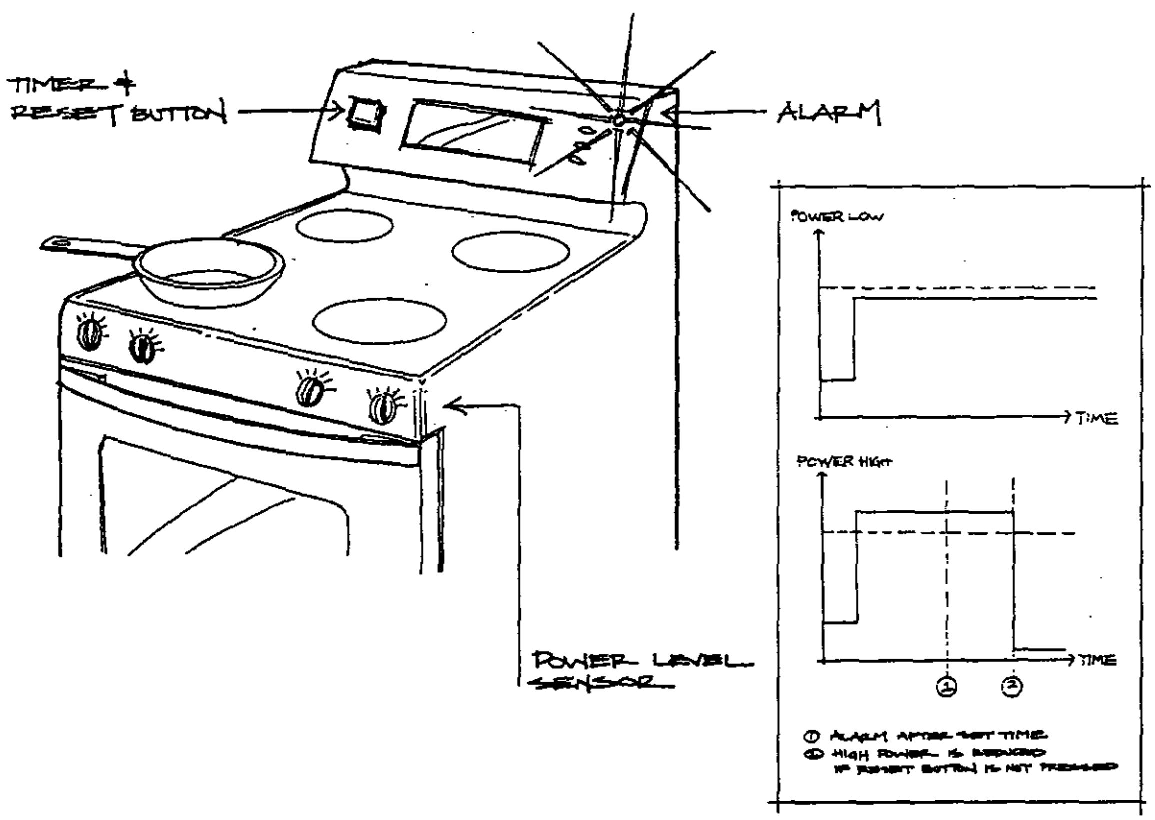


Figure 4-13: Prevent Unattended Cooking – Warning and Control – Power level sensor + timer

Prevent Unattended Cooking -- Warning Only -- Motion Sensor Only (Tech Class 14)

The next three technologies attempt to prevent unattended cooking through the use of a warning only. There is no follow-up control that would shut the unit down or reduce input in case no user is detected. In this case, a motion sensor detects the presence of a user near the cooktop. The location of the motion sensor may vary, but most patents show the sensor on the front panel of the cooktop. When the cooktop is operating, the sensor will monitor presence of user. If no user is detected after certain time period, an alarm will sound. The alarm will shut-off automatically if a person is detected nearby.

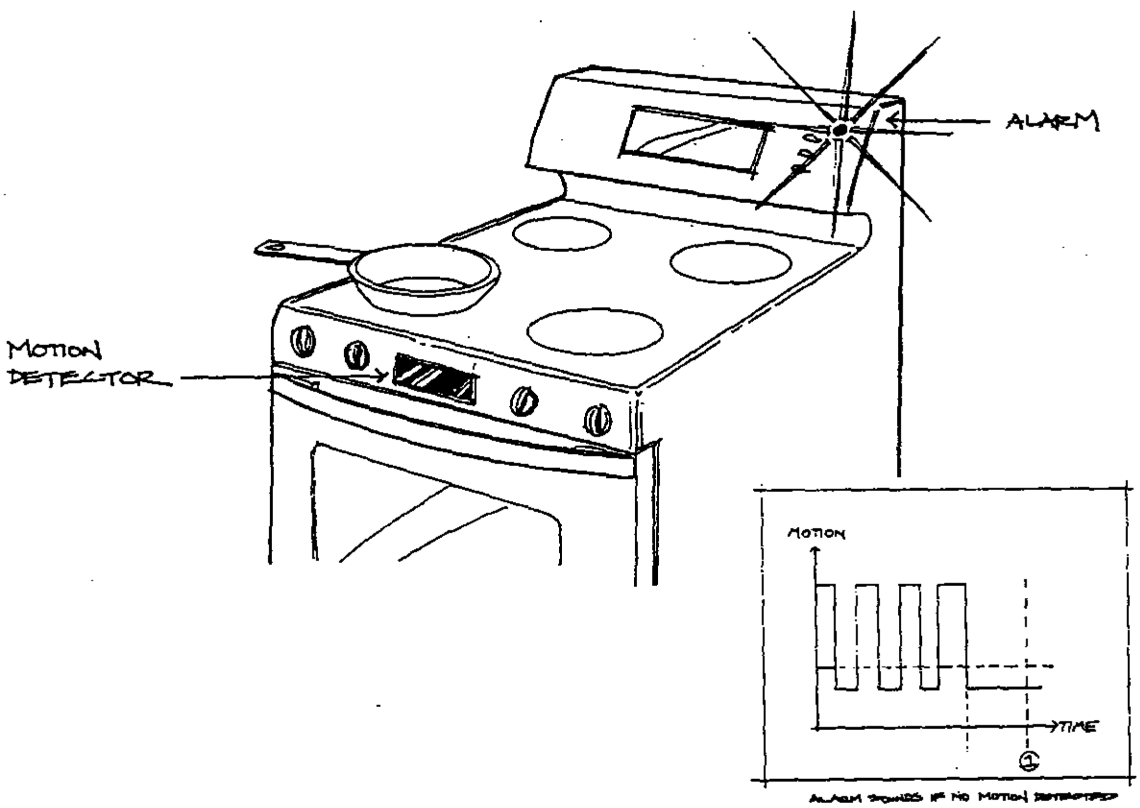


Figure 4-14: Prevent Unattended Cooking – Warning Only – Motion sensor only

Prevent Unattended Cooking -- Warning Only Motion + Power (Tech Class 15)

Again, this system attempts to prevent unattended cooking through a warning alarm, but no power level control. In this case, the safety system actuates only when a certain power level of the heat source has been surpassed (e.g. Medium-High level). When it actuates, the motion sensor detects the presence of a user near the cooktop. When no user is detected after a pre-set duration, an alarm sounds. The alarm shuts-off automatically once the motion sensor detects the user.

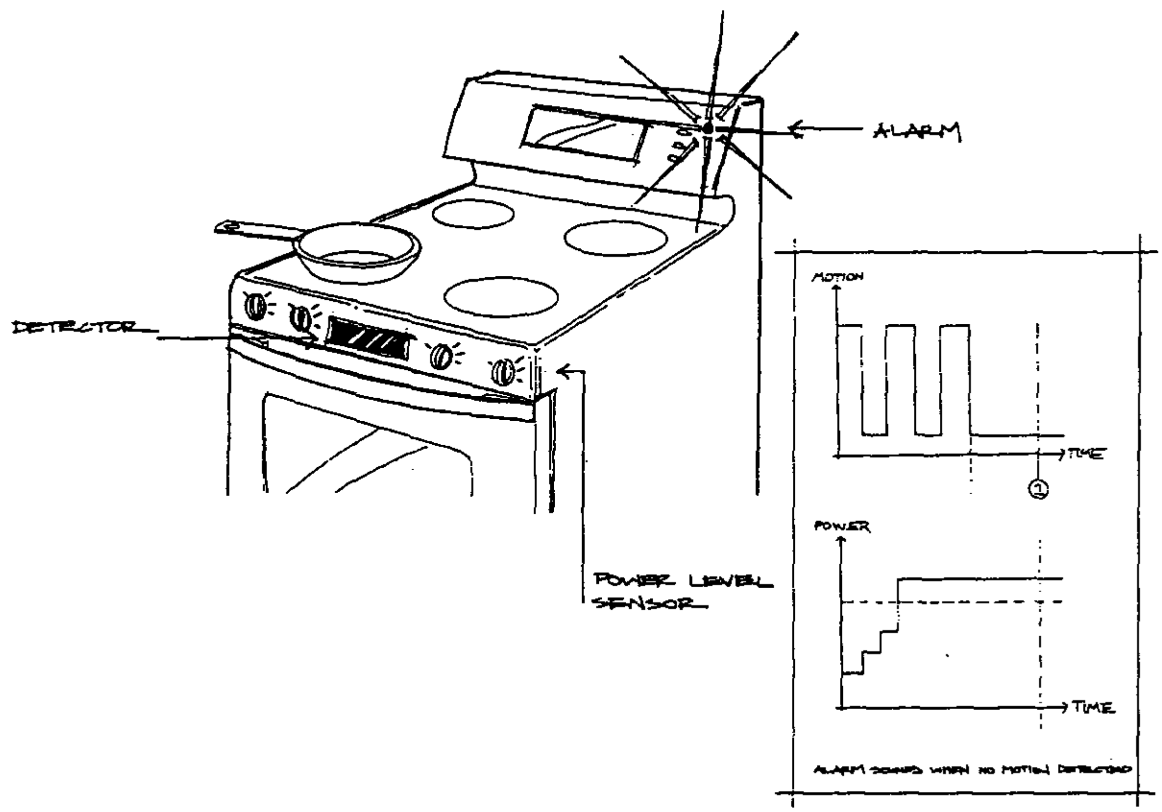


Figure 4-15: Prevent Unattended Cooking – Warning Only Motion + Power

Prevent Unattended Cooking -- Warning Only -- Power Level Sensor + Timer (Tech Class 16)

This technology to prevent unattended cooking utilizes a power level sensor and a timer to warn the user to attend the cooking process. An alarm will activate based on the power level selected and a timer that is a function of the power level. Specifically, a time interval is associated with the power level of the element or burner (this could be implemented with relays, and may not require an electronic micro-controller). A timer will trigger an alarm to sound after the element or burner has been turned on. The user would press a re-set button to establish user presence near the cooktop. In one system configuration, the system is actuated only at a power level above a minimum threshold level.

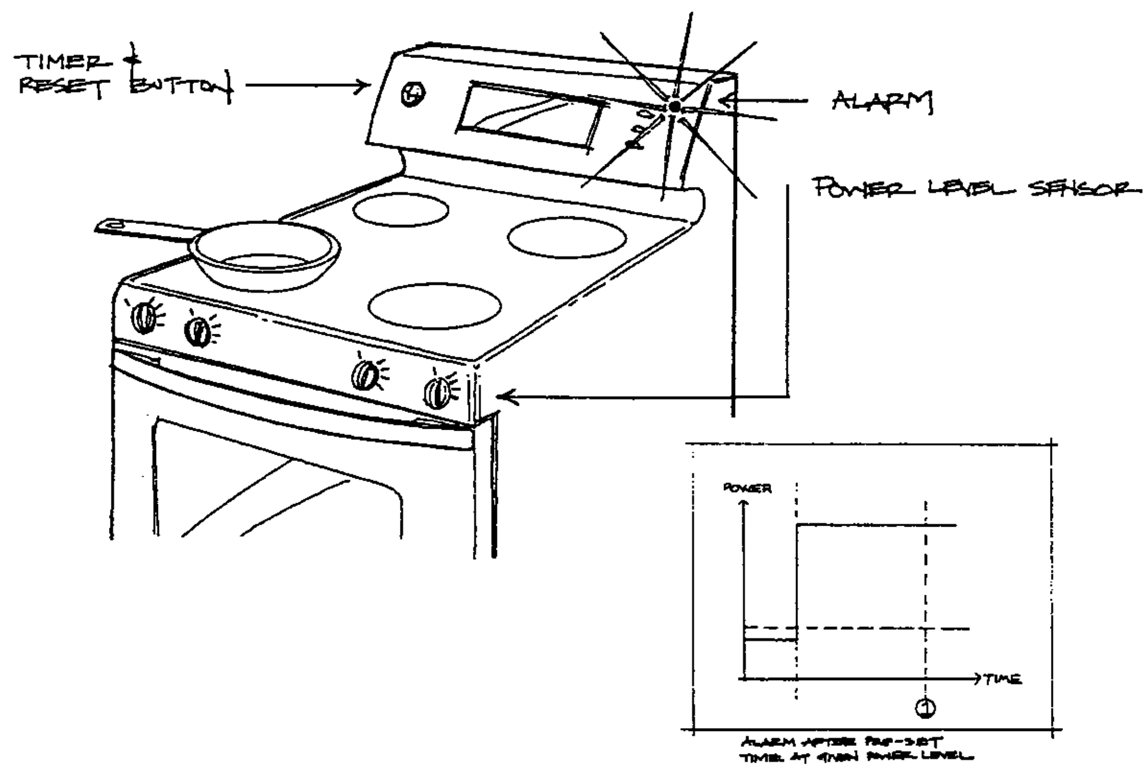


Figure 4-16: Prevent Unattended Cooking – Warning Only – Power level sensor + timer

Prevent Food Ignition in Pan -- Elec. Signal Processing, Select Mode or T -- T Sensor Contacts Pot (Tech Class 17)

The next five technologies are intended to prevent ignition of cooking materials in the pan. There are a number of approaches to control the heat input to the pan to avoid ignition. In this configuration, the safety system monitors the pan bottom temperature with a pan-contact temperature sensor (e.g. thermocouple). The controller is defined by a user-selected cooking mode (e.g. searing, boiling, frying) or a specified cooking temperature. A microprocessor control adjusts the heat input to the pot based on the cooking mode selected and the pan bottom temperature. This system prevents the temperature at the bottom of the pan from rising to a level that could cause ignition of cooking materials.

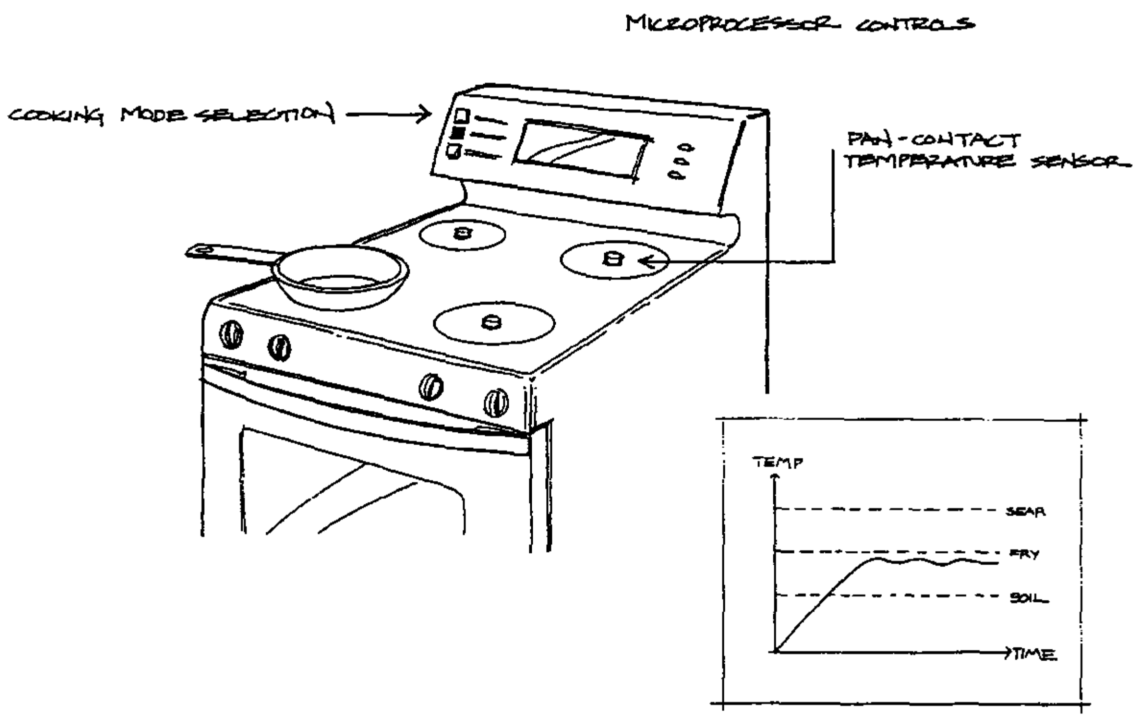


Figure 4-17: Prevent Food Ignition in Pan – Elec. Signal Processing, Select Mode or T -- T sensor contacts pot

Prevent Food Ignition in Pan -- Elec. Signal Processing, Select Mode or T -- Non-contact T sensor (Tech Class 18)

In this configuration, the safety system monitors the pan bottom temperature with a non-contact temperature sensor (e.g. IR sensor). The controller is defined by a user-selected cooking mode (e.g. searing, boiling, frying) or a specified cooking temperature. A microprocessor control adjusts the heat input to the pot based on the cooking mode selected and the pan temperature. This system prevents the pan temperature from rising to a level that could cause ignition of cooking materials.

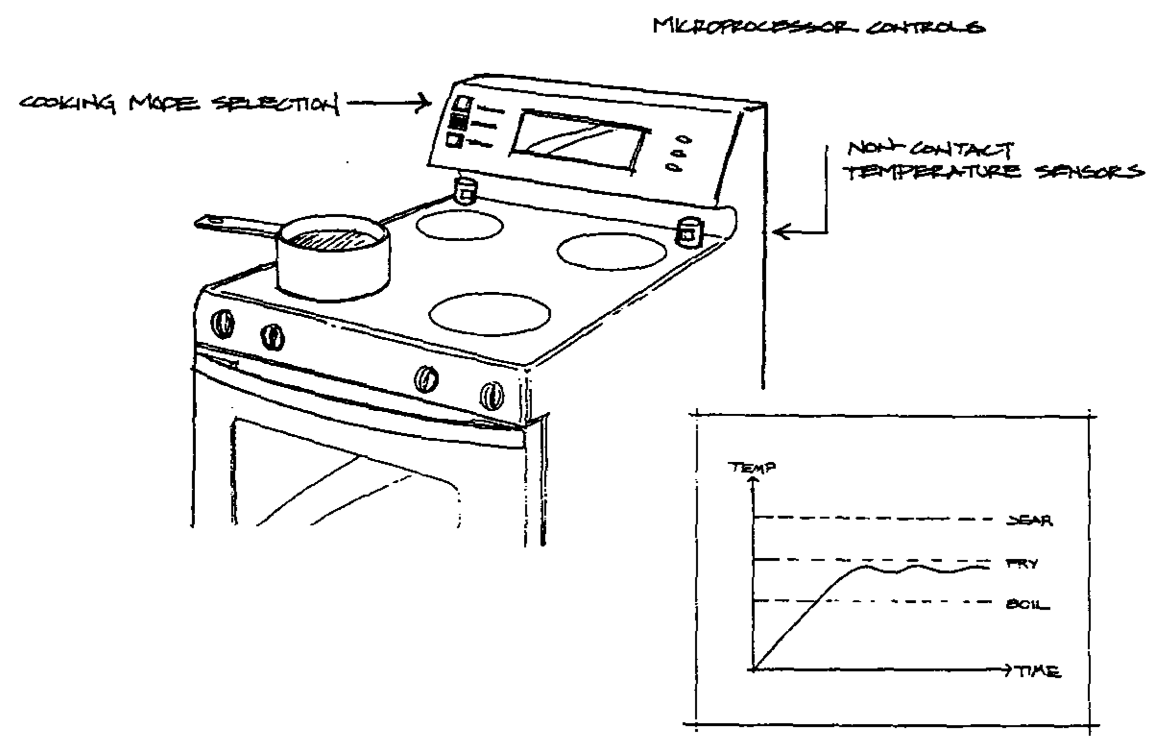


Figure 4-18: Prevent Food Ignition in Pan -- Elec. Signal Processing, Select Mode or T -- Non-contact T sensor

Prevent Food Ignition in Pan -- Elec. Signal Processing, Auto-activation -- T Sensor Contacts Pot (Tech Class 19)

In this configuration, the safety system monitors the pan bottom temperature with a pan-contact temperature sensor (e.g. thermocouple). The controller is configured to limit the temperature at the bottom of the pan to a threshold that is independent of the cooking mode. The threshold is selected to balance the requirements of various cooking modes and the limit to avoid ignition of cooking materials. A microprocessor control adjusts the heat input to the pot based on the pan bottom temperature. This system prevents the temperature at the bottom of the pan from rising to a level that could cause ignition of cooking materials.

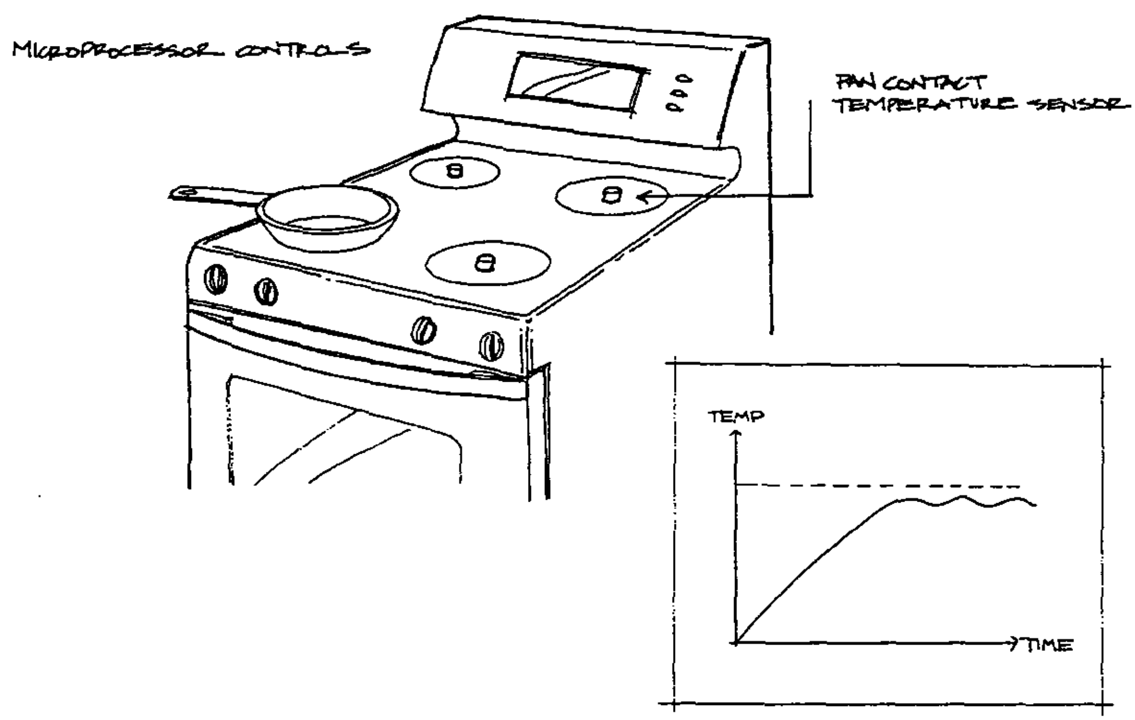


Figure 4-19: Prevent Food Ignition in Pan – Elec. Signal Processing, Auto-activation – T sensor contacts pot

Prevent Food Ignition in Pan -- Elec. Signal Processing, Auto-activation -- Non-Contact T Sensor (Tech Class 20)

In this configuration, the safety system monitors the pan temperature with a non-contact temperature sensor (e.g. IR sensor). The controller is configured to limit the pan to a threshold that is independent of the cooking mode. The threshold is selected to balance the requirements of various cooking modes and the temperature limit to avoid ignition of cooking materials. A microprocessor control adjusts the heat input to the pot based on the pan temperature. This system prevents the pan temperature from rising to a level that could cause ignition of cooking materials.

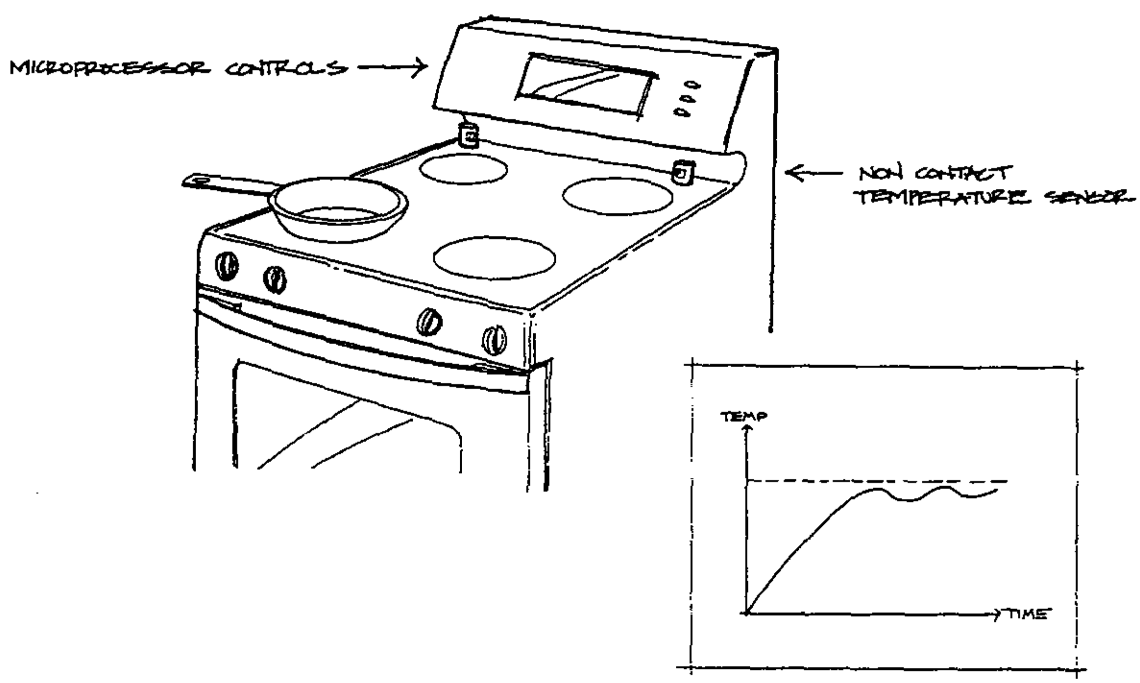


Figure 4-20: Prevent Food Ignition in Pan – Elec. Signal Processing, Auto-activation – Non-contact T sensor

Prevent Food Ignition in Pan -- No Signal Processing, Mechanical Actuation (Tech Class 21)

The safety system monitors the pan temperature with a pan-contact temperature sensor. The mode of actuation is mechanical instead of electrical. The temperature sensor used can be bi-metallic piece that will bend at certain pre-set temperature, a magnetized piece that changes properties at certain temperature, or an expandable liquid sensor. This type of technology has been used as either a heat-source regulating device or a one-time shut-off device.

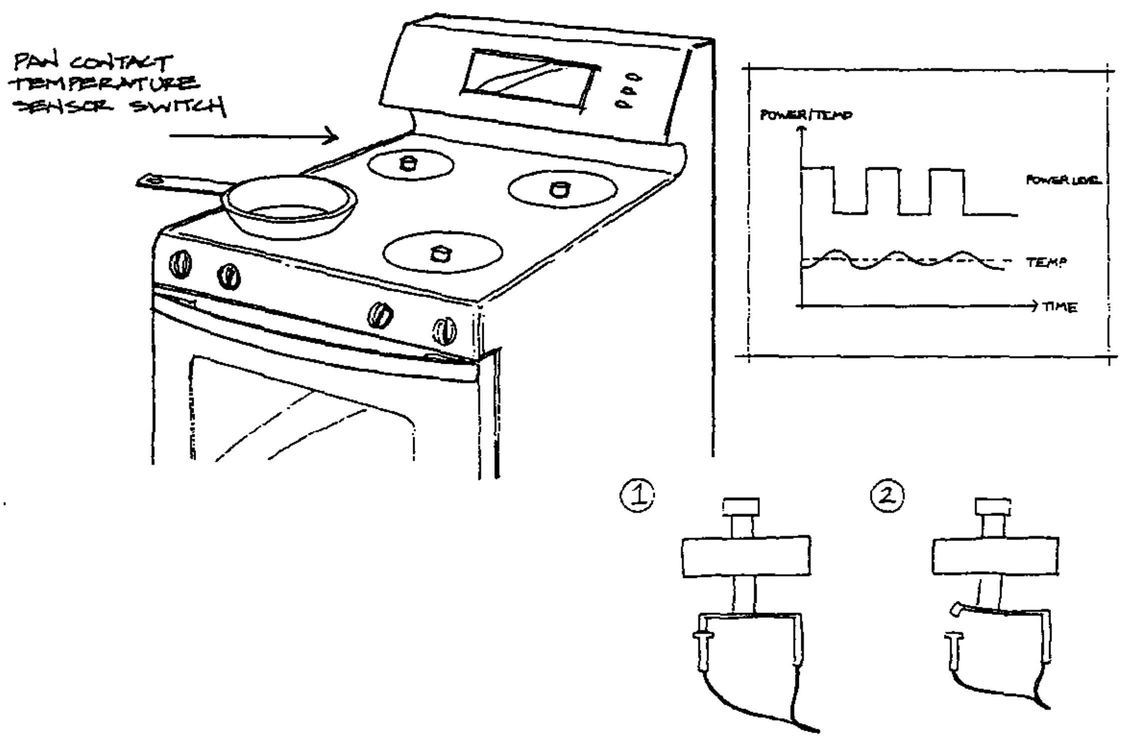


Figure 4-21: Prevent Food Ignition in Pan -- No Signal Processing, Mechanical actuation

Prevent Boil Dry/Spill Over –Temperature Sensor (Tech Class 22)

In this technology, the temperature of cooking utensil is monitored. The sensor technology can be a pan-contact thermocouple, or it could be an optical or non-optical temperature sensor. The basic element of this approach is the detection of a temperature signature for boil dry or spill over (e.g. sharp increase of temperature after a constant temperature reading). The controller is configured to shut-off the temperature to the element or gas burner after the boil-dry condition has been detected.

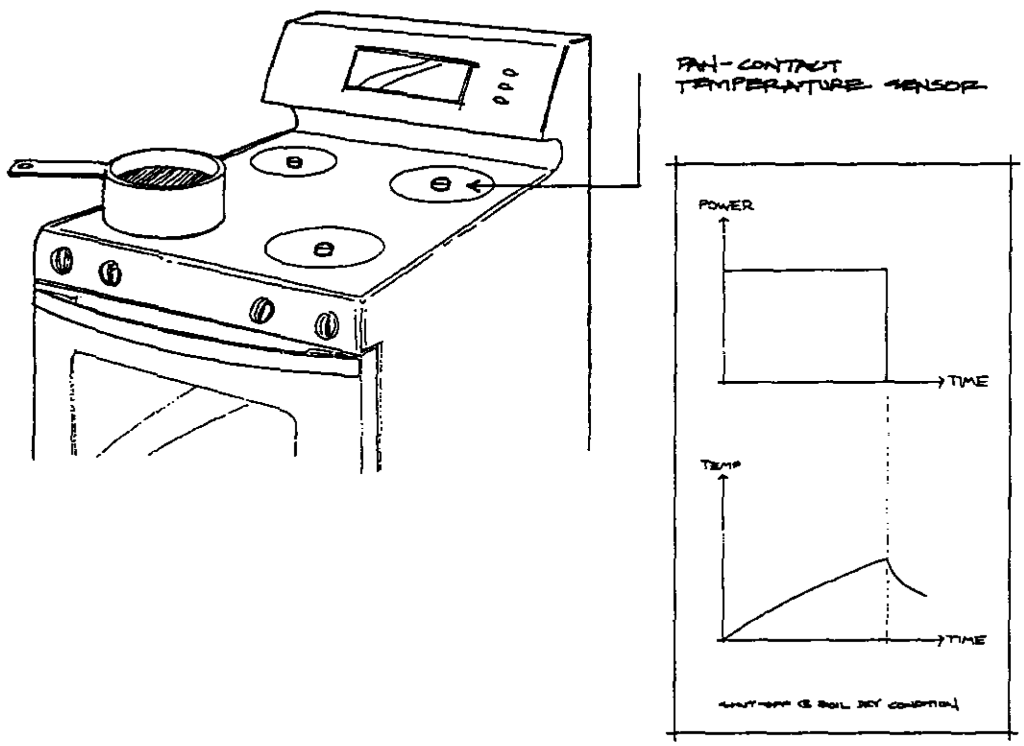


Figure 4-22: Prevent Boil Dry/Spill Over –T sensor

4.3 Screening Criteria

We developed screening criteria for these technologies based on two sets of *considerations:*

1) The potential impact of the technology on the cooking performance, operability, reliability/durability, safety, and manufacturability/installation/service of the cooktop or range; and
2) The potential effectiveness of the technology to mitigate surface cooking fires.

All the criteria and metrics used to screen, and ultimately evaluate, the surface-cooking, fire-mitigation technologies are listed below.

1. Cooking Performance:

- Effect on Cooking Process:
  - High: Works well with all surface cooking functions
  - *Medium: One cooking function is eliminated or negatively affected*
  - Low: More than one cooking function eliminated or negatively affected
- Effect on Cooking Time:
  - High: None
  - Medium: Some (Less than 10%)
  - Low: Significant (Equal or More than 10%)

2. Cooktop Operability

- Effect of System on Consumer Behavior While Operating the Cooktop
  - High: New user will not notice any difference in operating procedure compared with conventional cooktop
  - *Medium*: New user *will notice difference(s) in procedure but it will* be intuitive enough that he/she will not need a manual to operate
  - Low: New user will need to learn new skills through a product manual in order to operate cooktop

- *Limits availability or efficacy of marketed cooktop features*
  - High: New user will not notice any difference in product features
  - Medium: New user will notice difference(s) in product features
  - Low: Desirable product features are eliminated

- Safety System Maintenance:
  - High: System maintenance procedure is the same as a conventional cooktop
  - Medium: System maintenance requires few additional procedures/parts that do not require specialist's help
  - Low: System maintenance requires significant additional procedures/parts that might require specialist's help

- Cookware Applicability:
  - High: System works with any utensils, and at normal environment
  - Medium: Some restrictions on cookware or environment
  - Low: Specific set of applicable tools/utensils are needed

- Effect of Safety System on Cooktop Performance After Actuation of System:
  - High: Cooktop can perform normally as before safety actuation
  - Medium: Minor adjustment or cleaning necessary to return it to nominal operation
  - Low: Significant adjustment or cleaning or service call necessary

3. Reliability/Durability

- Can operate over product life w/o failure (safety factor of 2):
  (Considers normal cooktop cleaning (or non-cleaning) and maintenance)
  - High: Meets targets / Life data available/conducted
  - Medium: Looks good but no data
  - Low: Looks problematic, no data

- Can operate within reasonably foreseeable misuse conditions (durability)
  - High: Is robust/durability data available/conducted
  - Medium: Looks good but no data
  - Low: Looks problematic but no data

4. **Safety**

- Safety system components might pose added risk to consumer:
  - High: None
  - Medium: Some but easily and obviously modifiable
  - Low: Some and not easily or obviously modifiable

5. **Manufacturability/Installation/Service:**

- Applicability across product types and product models
  - High: Developed to be applicable to all cooktop systems
  - Medium: Can work for all models of one product type, e.g., sealed burners, open burner, open coil, glass ceramic, gas pilot, downdraft systems
  - Low: May require different design for functionally different models within a product type

- Components/system availability
  - High: All parts are on-the-shelf parts or have been manufactured for high volume low cost applications.
  - Medium: Most parts are available on-the-shelf or have been manufactured in high volume at low cost
  - Low: Most parts are new parts that need to be developed and manufactured or adapted from other industries

- Installation
  - High: No added effort than installing range
  - Medium: More time but no added people to install.
  - Low: Additional tradesmen and/or technicians required for installation

- Serviceability
  - High: Current staff can conduct routine maintenance with existing equipment.
  - Medium: Some training and/or new equipment is necessary.
  - Low: Specialized equipment and staff expertise or licensing is necessary.

6. Effectiveness in Mitigating Surface Cooking Fires

- Range of Fire Incident Coverage (Based on existing fire data)
  - High: Would address over 90% of surface cooking fires, based on the categories defined in NFPA study.
  - Medium: Would address between 40% - 90% of surface cooking fires
  - Low: Would address fewer than 40% of surface cooking fires

- Percent of new product sales covered by this technology
  - High: Would cover over 90% of new surface cooking products.
  - Medium: Would cover between 40% - 90% of new surface cooking products
  - Low: Would address fewer than 40% of new surface cooking products

- The degree of mitigation of fires addressed:
  - High: Prevents a fire from starting
  - Medium: Extinguishes/Manages a fire
  - Low: Warns of a Fire

- Ease of System Verification
  - High: Automatically verifies proper operation
  - Medium: User can verify operation with self test mode
  - Low: Verification of operation possible by service tech

- Potential for False Actuation:
  - High: "No" chance for false positive or false negative
  - Medium: Potential for false positive
  - Low: Potential for false negative

- Effect of Actuation on the Safety System:
  - High: Safety system does not require consumer reset (and this is safe)
  - Medium: Users have to manually reset the safety system (e.g. a press of a button)
  - Low: Service call or component replacement/recharging necessary for the safety system to return to its ready state

- Safety system's effect on cooktop's requirement to meet current safety standards (UL/ANSI); i.e. need to fail safe (cooking system shuts-down if safety system is not working):
  - *High:* *In full compliance with standards*
  - *Medium:* *Can be easily and obviously modified to achieve compliance*
  - *Low:* *No obvious modification available to achieve compliance*

4.4 Additional Considerations for Technology Evaluation

There were a number of additional considerations that formed the basis of the technology screening and evaluation work. These considerations are summarized in the following five sections.

4.4.1 Cooking Processes

We used criteria set forth by the ANSI Z21/UL 858 STP Cooking Fires Working Group to establish the cooking requirements of any range or cooktop coupled with a fire mitigation technology. Specifically, we used this group's list of cooking tests as a starting point for establishing the types of cooking processes that any cooking product would be required to provide. These cooking processes included:

- Blackening meat or fish in a skillet;
- Stir Frying Vegetables or Meat in a Wok;
- Boiling 1, 2, and 4 quarts of water in appropriately sized sauce pans;
- Heating and simmering sauces in 1 and 2 quart pans;
- Deep fat frying (repeatedly); and
- Canning (boiling and maintaining the boil of 8 quarts of water for 4-6 hours).

In addition, we added the following cooking processes to the list:

- Putting a kettle on to boil, (and leaving the kitchen); and
- Preparing a 'flambé', wherein the alcohol poured into a pan is burned off.

We used these cooking processes as a benchmark to evaluate whether fire mitigation technologies 'would work well with all surface cooking functions'.

A complete list of the definitions we have used for specific cooking processes is included in Appendix C.

4.4.2 Cooking Time

The effect of a fire mitigation technology on cooking time is an area of considerable concern for the industry. Market forces are continuously demanding cooking technologies that provide added convenience. In surface cooking, this market demand translates into the need to reduce the time required to bring foods to their desired temperature (e.g. the time to boil, or the time to heat oil to the desired temperature).

There is general industry concern that a technology that limits the pan temperature to below a pre-ignition condition could have an adverse affect on cooking time. In addition, there is general concern that the temperature at the bottom of the pan may not accurately indicate the temperature of the cooking materials in the pan. Some of the tests conducted by Good Housekeeping on the CPSC cooking control prototype showed significant increases in cooking times for certain cooking functions. However, the existing data did not reveal the cause of the increased cooking times. In our meetings with appliance manufacturers, they did not identify any existing data on cooking process temperature or the measurements of pan temperatures under various cooking conditions.

In order to evaluate the potential efficacy of a pre-ignition threshold controller, we needed to determine the pan temperatures required for a set of standard cooking procedures and compare these temperatures to the thresholds used to avoid a pre-ignition condition. In a limited number of focused tests in our labs at Arthur D. Little, we examined:

1) the pan temperature associated with boiling, searing, and frying, and
2) the control temperature thresholds of the two CPSC prototypes (a Magic Chef gas range fitted with a prototype safety system, and a Hotpoint electric range fitted with a different prototype safety system), and a commercially available, Japanese residential cooker made by Rinnai with the SAFULL pan temperature control function intended to prevent overcooking, burning and overheating of deep frying oil. .

We compared these temperatures to the pre-ignition thresholds for oils identified in the literature (e.g. the CPSC studies, AHAM food test program, edible oil data, etc.)

In a series of experiments using a variety of pan types (stainless steel, aluminum, cast iron), we measured the temperatures of the pan bottom and pan contents during various cooking procedures. Pan bottom temperatures were measured at the center and edge of the pan, using K-type thermocouples drilled into the base of the pan. Pan contents temperature was measured using a third thermocouple placed into the liquid or pushed into the steak.

First, we confirmed the range of temperatures at which cooking oil would ignite in our setup, by heating oil on a burner with no safety system acting until ignition occurred. The results were consistent with the significant body of data available on oil ignition temperatures. The figure below shows the temperature ranges determined by us and those quoted by other sources. The results of analysis and ignition tests of used oil are described in Appendix G.

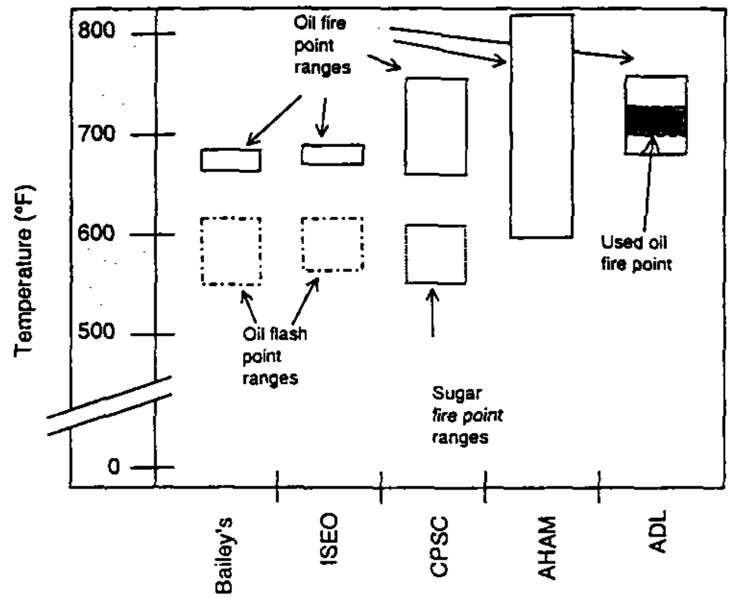


Figure 4-23: Food ignition temperatures.

Sources: Bailey's Industrial Oil and Fat Products; Institute of Shortening and Edible Oils (ISEO); CPSC Study (Phase III Report); AHAM "Food Fire" Test Program; ADL Tests. Fire point =Temperature at which spontaneous ignition can occur, Flash point = point at which external flame will cause ignition).

Next, we investigated the different temperature regimes for a variety of cooking procedures. We allowed different quantities of water to boil normally, with no safety system acting. Frying was simulated by heating oil on the Rinnai burner, using the setting that is designed to maintain the highest optimum temperature for frying food (390°F). Steaks were pan-seared by an experienced cook, again with no safety system acting.

The figures below show the temperature ranges involved in the different processes. The first figure shows food temperatures. The second figure shows pan bottom temperatures.

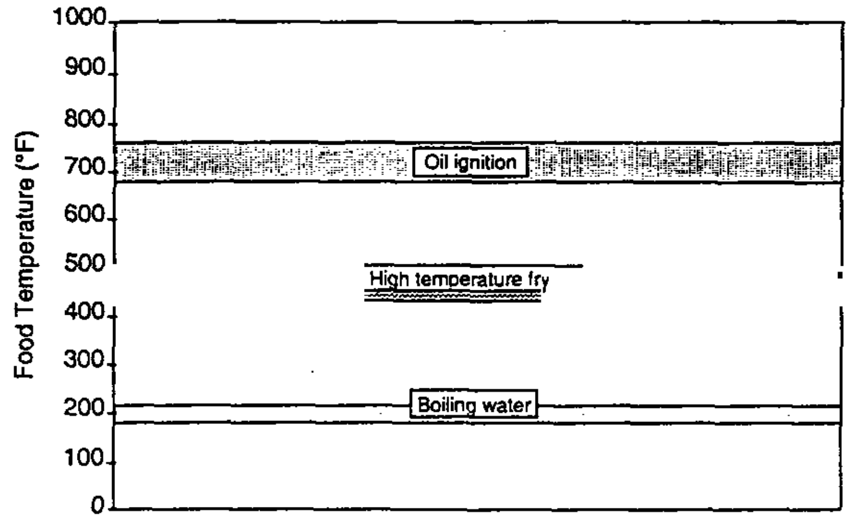


Figure 4-24: Temperature of pan contents during various cooking procedures

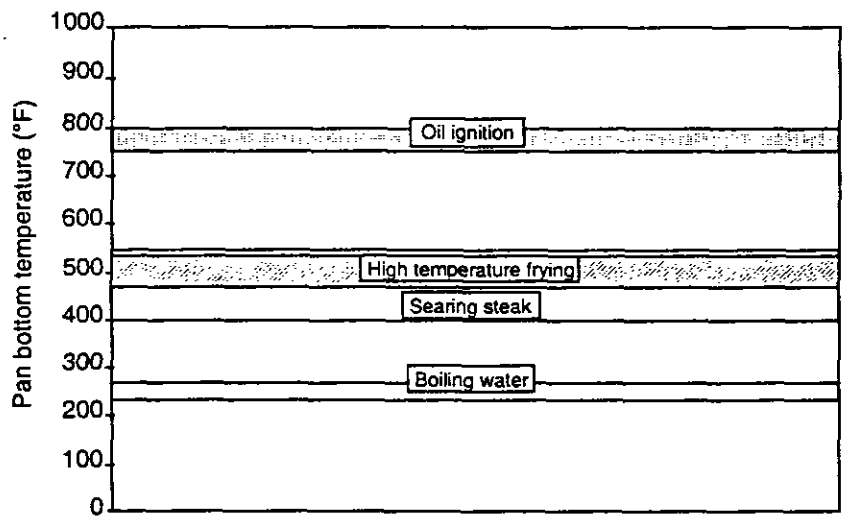


Figure 4-25: Temperature of pan bottom (at center of pan) during various cooking procedures

These figures indicate that the temperatures reached by both the food and pan bottom during normal cooking procedures are significantly lower than those experienced when ignition occurs. With an accurate, robust method of measuring pan temperature, it would in theory be possible to implement a threshold-based temperature control algorithm that should prevent ignition from occurring without affecting normal cooking. The issue is one of engineering design, not of fundamental principles.

However, the two prototype systems that we tested demonstrated the difficulty of designing an accurate pan bottom temperature sensor for this application. Both the electric and gas cooktops used spring-loaded thermocouple temperature probes that protruded above the electric ring or burner grate. When the pan was placed on the heating element, the temperature probe was depressed but remained in contact with the pan bottom. The sensor on the gas stove used a shield around the probe to try to insulate it from the flame. As the graph below shows, we recorded large differences between the temperatures measured by the probes and those measured by the thermocouples we had embedded into the pan bases, particularly with the electric cooktop system.

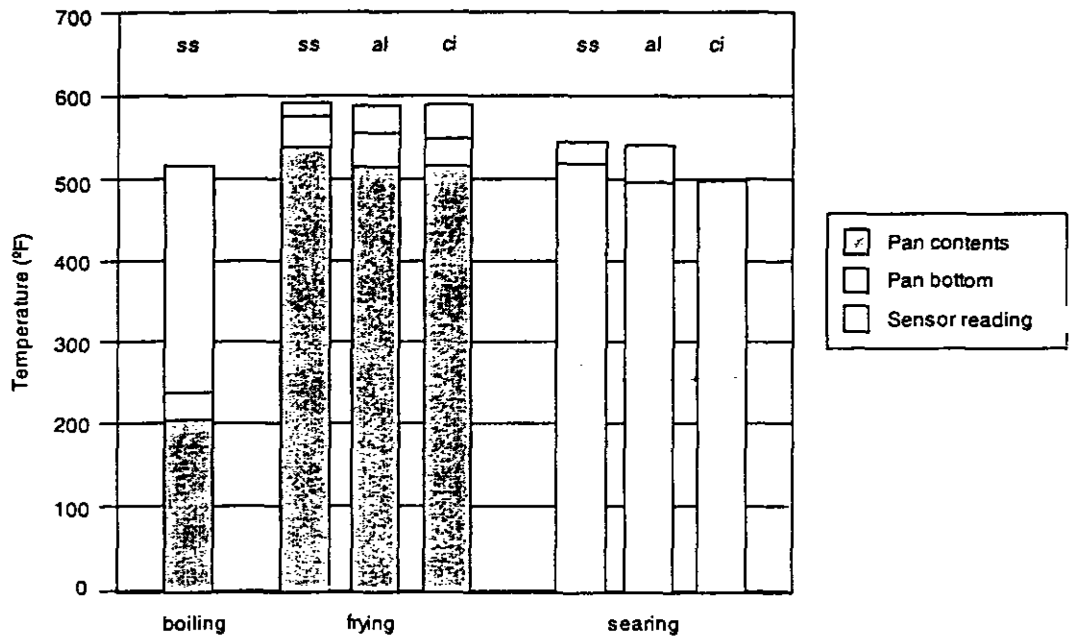


Figure 4-26: Differences between sensor readings and pan bottom & contents temperatures

Shielded, Centered Probe used in the CPSC gas-range prototype controller.
***ss = stainless steel pan ; al = aluminum pan; ci = cast iron pan.* Pan contents temperatures are not shown for searing.**

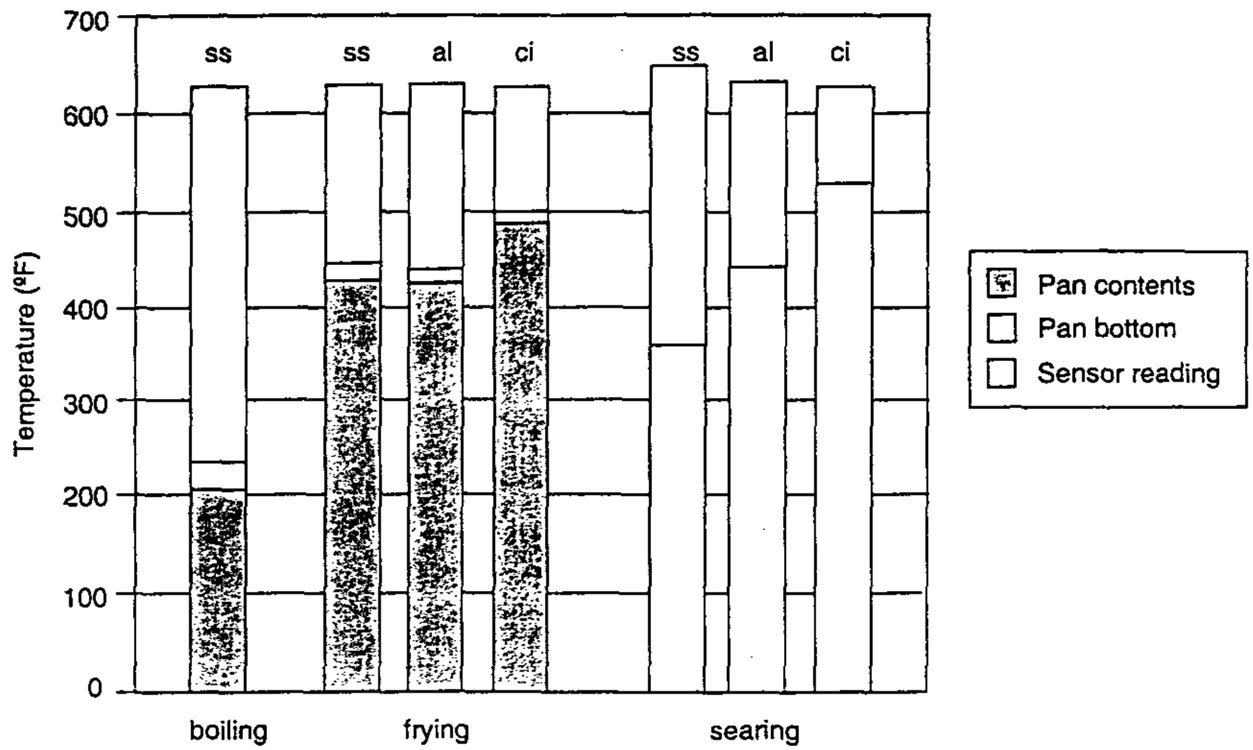


Figure 4-27: Differences between sensor readings and pan bottom & contents

Unshielded, through-coil probes (Temperature measured is maximum of the 3 probes) used on the CPSC prototype electric cooktop controller. ss = stainless steel pan ; al = aluminum pan; ci = cast iron pan. Pan contents temperatures are not shown for searing.

The safety systems were triggered when the measured temperatures exceeded a pre-set threshold. Because the probes were reading temperatures much higher than the pan bottom had actually reached, this limited the pan bottom temperature to a significantly lower threshold. As a result, in some cases, the pan did not get hot enough to produce good searing of the steak or even to allow a rolling boil.

This analysis provided some insights to the basis of the cooking performance of the current CPSC pre-ignition control prototypes. The tests and analysis also shed some light as to the engineering requirements for these types of safety systems.

See Appendix D for detailed plots of temperature measurements during the cooking tests.

4.4.3 Fire incident statistics used

We reviewed a variety of fire incident statistics in order to associate surface fire mitigation technologies with the fraction of fire incidents that potentially could be addressed by the technology. The fire statistics that we reviewed included:

Ten Community Study of the Behaviors and Profiles of People Involved in Residential Cooking Fires, Executive Summary, National Association of State Fire Marshals, Cooking Fires Task Force, AHAM Safe Cooking Campaign, July 1996 (Includes research conducted from 1995 through 1996).

US Home Cooking Fire Patterns and Trends, John Hall Jr., Fire Analysis and Research Division, National Fire Protection Association, April 2000 (and previous reports) The latest data contained in this study are from 1997.

Range Fires, Characteristics Reported in National Fire Data and a CPSC Special Study, Linda Smith et al, US Consumer Product Safety Commission, Hazard Analysis Division Directorate of Epidemiology and Health Sciences, January 1999.

The primary statistics that we used from these reports are as follows:

- Surface cooking represents between 73 – 83% of cooking fires, depending on the analysis;
- Depending on the analysis, between 58 – 85% of the surface cooking fires were unattended at the time of ignition.
- Cooking materials were ignited first in 72 – 77% of surface cooking fires.
- Half of homeowners who attempted to fight a cooking fire did the wrong thing.
- The cooking materials that do ignite are primarily greases, oils, meats, fish or starches.

We used these statistics in the following aspects of our evaluation work.

- The basis for focusing on surface cooking fires was confirmed. The significance of both unattended cooking and the ignition of cooking materials as factors in cooking fires was confirmed.
- We eliminated all patents, technologies, products or concepts that required a person to approach the fire or address it manually in any way. We eliminated these approaches because the statistics indicated that half of people who attempt to respond to a kitchen fire do the wrong thing. Fire marshals recommend leaving the area of the fire and calling the fire department. We wanted to be consistent with this recommendation.
- Fire extinguishing technologies that were not intended to address oil or grease fires were eliminated from consideration.
- We used the statistics to estimate the potential effectiveness of certain fire mitigation approaches. These numbers are only general estimates; they are useful for evaluating the relative impact of technologies. We averaged the varied numbers from the various reports as follows:
  - Requiring someone to attend to cooking was estimated, for the purpose of comparison, to mitigate 65 - 70% of surface cooking fires.
  - Preventing cooking materials from igniting was estimated, for the purpose of comparison, to mitigate 72% of gas surface cooking fires and 77% of electric surface cooking fires. The total effectiveness of a technology intended to prevent the ignition of cooking materials is also dependent on the applicability of the

technology to specific product types and the sales volume of the applicable product types. (Data used on product types is included in Section 4.4.5.)

4.4.4 Reliability/Durability

The ANSI Z21/UL 858 STP Cooking Fires Working Group outlined the reliability/durability requirements for any system that would be associated with a range or cooktop. We considered these requirements in our analysis of the various fire mitigation technologies. For the most part, there was insufficient data to determine conclusively whether the technologies could pass the defined tests. However, the group's guidelines for the requirements of any technology are listed below. Not all the requirements are pertinent to all the potential fire mitigation technologies. Reliability is clearly an important open item that would need to be addressed directly as part of a product development process for any new safety system.

- Perform as designed for twice its design life. It is recommended for safety components to have minimum of 100,000 cycles.
- Control components removed and installed 2,000 times without need for re-calibration – based on one disassembly operation for cleaning per week for 20 years with a 2x safety factor applied
- A burner needs to be cleaned thoroughly w/ washcloths and standard household cleaners for a total of 15,000 cycles (based on one cleaning per day over 20 years with 2x safety factor.
- Control components shall perform as designed after dragging 12" diameter. cast iron with heavy pattern/ribbed surface. The pan is assumed to be drawn across burner with a horizontal motion of 4-6 inches for a minimum of 50,000 times: This corresponds to pan movement for 2-3 times per day for 20 years with 2x safety factor.
- If a sensor is attached to a heating element where disassembly is allowed for cleaning, it should be removed and installed 2,000 times and reseated using 12" cast iron pan with a downward force (not impact) of TBD lbs
- Performance and reliability tests on used and new burner and components using: soil build-up, oxidation, water and grease, baked on or burnt on food materials -- use food mixture shown in ANSI Z21.1 or AHAM ER-1-1992 Section 8.6. Sensor should detect all required safety parameters without change in calibration.
- Depending on the type of sensor, performance and reliability tests at environmental condition of: Hood fan on high (250-300 CFM), in 85% humidity, 20% humidity and altitudes of 3000 feet
- For fire management system mounted on hood:
  a. Surface temperature at any point of the top building cabinet should not exceed 300C (572°F)
  b. A fuse rated 3A connected between exposed dead-metal parts of cooking appliance and ground should not open
- For gas ranges, any components shall show no degradation when shut-down of range is applied. Any shut-down of gas valve shall allow safe restart without attention by service personnel.

4.4.5 Product Classes

We have used industry statistics and definitions of product classes in order to associate specific products with relevant fire mitigation technologies.

Gas and electric cooking products are classified into the following product categories:

- Free-standing Ranges – a stand-alone cooking product with cooktop and oven
- Drop-in (slide-in) Ranges – a cooking product with a cooktop and oven that is designed to be built into a cabinet/counter.
- Surface Cooking Units- a cooktop that is installed into a countertop.

Any of these product classes can be constructed in a downdraft configuration, meaning that a ventilation system is integral to the cooking product and no hood would be required/installed.

Gas units are further divided into the following product categories:

- Open Burners
  - With pilot
  - Electronic Ignition
- Sealed Burners

Electric units are further divided into the following product categories

- Smoothtop (glass ceramic)
- Open coil

In our analysis, we needed sales numbers (in percentages) associated with the following product categories. We have made estimates of these numbers based on AHAM data and information provided to us by manufacturers.

Overall sales percentages (and trends) are shown in the following graph:

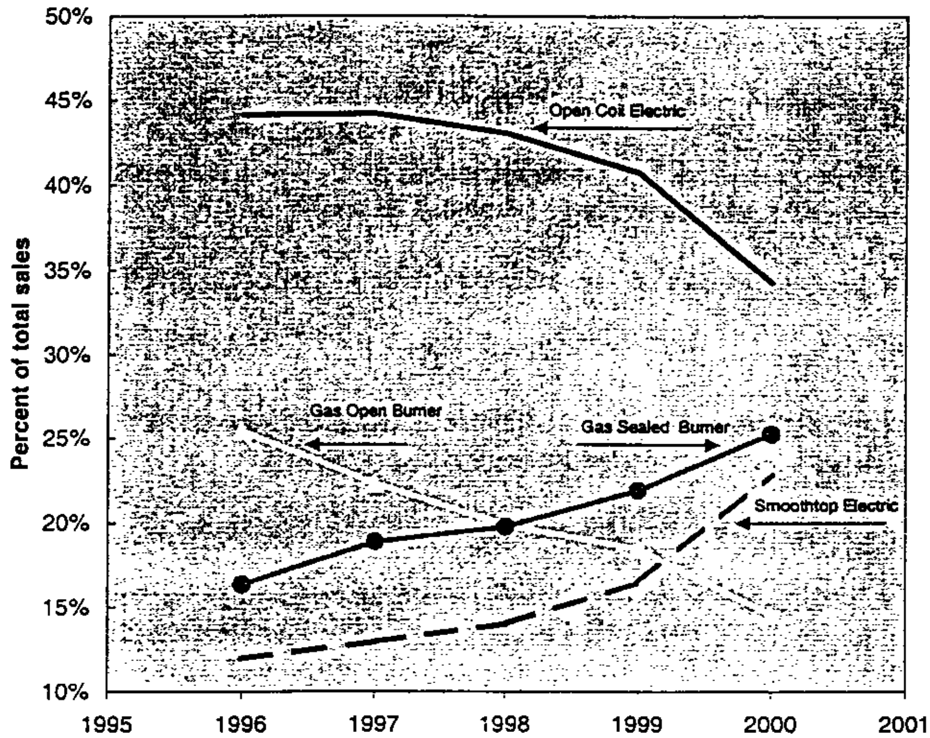


Figure 4-28: Trends in cooking product mix

- Percentage of products overall that currently have an electric connection (>90%)
- Percentage of surface cooking products that are installed in an island or peninsula configuration that would inhibit (or make more complex) the installation of an overhead hood. (<10%)
- Percentage of surface cooking products with downdraft ventilation (<10%)

4.5 Technology Screen

We evaluated each Technology Class listed in Section 4-2 in accordance with the Screening Criteria listed in Section 4-3. In the scoring process, a numerical score of 9 corresponded to a High score, 5 corresponded to a Medium score and 1 corresponded with a Low score. The scores of each technology are detailed in Appendix E. The basis of each score is detailed in Appendix F.

A graphical representation of the results of this screening process is shown in Figure 4 – 29. The technology scores are plotted on the axes of "Impact on Product Value" and "Effectiveness in Mitigating Surface Cooking Fires". A technology that is relatively more effective in mitigating surface cooking fires, with limited impact on other aspects of the product value, would be plotted in the upper right hand corner of the graph.

This screening process was effective in providing a comparison among a set of very different technologies. It helped to highlight a subset of technologies for further consideration.

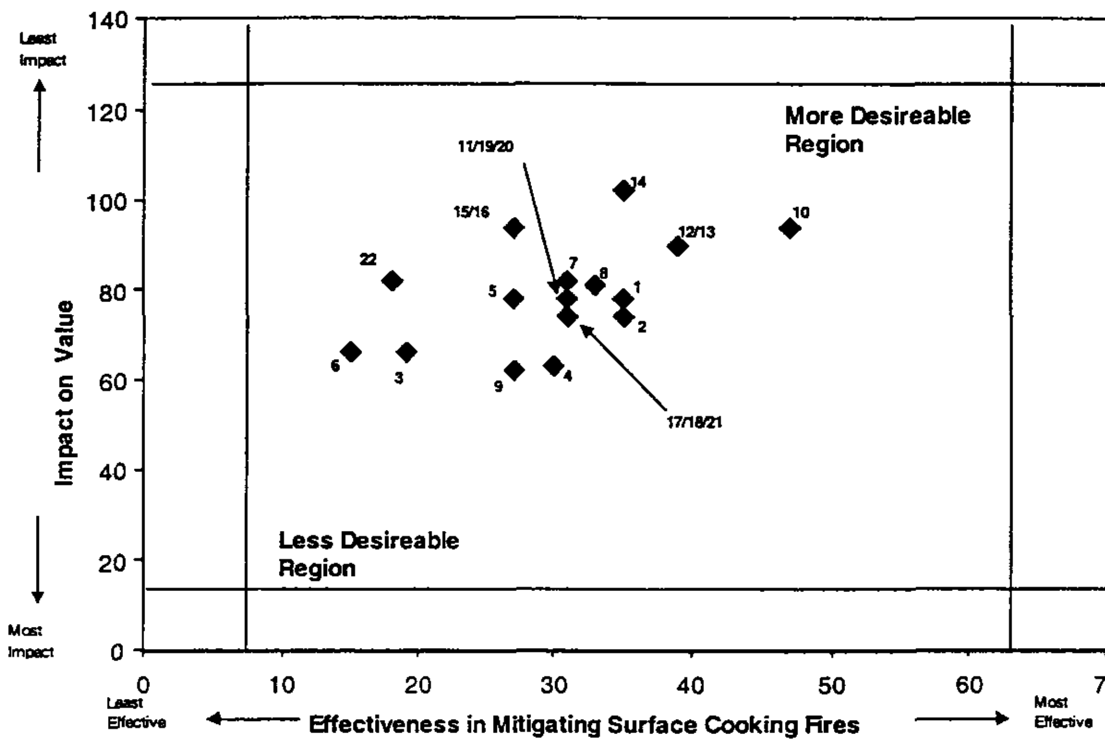


Figure 4-29: Technology Screening Results

The technologies that are clustered in the upper right hand corner of the graph are listed below:

1) Detect and Extinguish Fire: Fusible Link for Fire Detection (Tech Class 1)

   This technology scores relatively highly because it has minimal effect on consumer behavior, cooking performance or the operation of the cooktop. There are other areas in which the technology does not score highly, related to: ease of installation and service, the ability of the technology to 'fail-safe', and the impact of system actuation on the cooktop and the safety system itself. With regard to the effectiveness in mitigating fires, it is triggered by the presence of a fire, so some damage may already be done before the safety system actuates. It is not readily applicable to installations on islands or in association with cooktops with integral downdraft ventilation systems.

2) Detect and Extinguish Fire: Non-optical Temperature Sensor for Fire Detection (Tech Class 2)

This technology is a minor variant on the technology described above. It scored very similarly.

3) Prevent Unattended Cooking -- Warning and Control -- Motion sensor only (Tech Class 10)

This technology will have an impact on consumer behavior and available cooking processes. It scores highly in safety system effectiveness because it is intended to prevent a fire from igniting, it is applicable to most product classes, can be made to be 'fail safe'. The basic assumption here is that if a significant amount of fires occur when someone is out of the kitchen, then requiring the cook to remain in the kitchen will prevent these fires from occurring.

4) Prevent Unattended Cooking -- Warning Only -- Motion sensor only (Tech Class 14)

This technology scores similarly to the one above except that it is potentially less effective in preventing fires, but it may be less restrictive on consumer behavior as well.

5) Prevent Unattended Cooking -- Warning and Control -- Motion + Power sensor (Tech Class 12)

This approach has the same objective as the use of a motion sensor alone, but the addition of a power level sensor is an effort to allow some cooking processes to proceed unattended. One concern with the approach is that it will require a level of effort to implement on a gas system. In addition, because it allows some cooking to take place unattended, it may be less effective in mitigating fires than some other technology options.

6) Prevent Unattended Cooking -- Warning and Control -- Power level sensor + timer (Tech Class 13)

This approach scores exactly the same as Technology Class 12, with the timer, analogous to the motion detector, requiring the presence of the cook near the rangetop.

4.6 Selected Technologies

This screening task was to provide a guideline for eliminating some technologies from further consideration and selecting others for detailed evaluation. It was not intended to be used followed 'blindly'. We looked at technologies that did not score well and considered whether there was any opportunity for improvements in effectiveness or impact based on additional development work. We also looked at the set of technologies that were being selected to determine whether they represented a reasonable 'portfolio' of approaches for fire mitigation.

We added one more technology class to those listed above for more detailed evaluation. We added Technology Class 19 that would prevent food ignition in a pan by controlling pan temperature through a contact temperature sensor. The reasons for adding this technology are:

- A significant amount of work has been conducted on this approach to cooking fire mitigation. In addition, cooking products are manufactured and sold in Japan that use this approach. These factors warranted a more detailed evaluation of its potential in comparison with other technologies
- One of the reasons that this approach did not score highly in the technology screen is that it is unlikely that the approach is applicable to electric smoothtop systems. However, it may be a reasonable solution for coil or gas cooktops, and thus did not warrant being dismissed.
- After analyzing the reasons that the current prototypes did not perform well, we believed that there was some opportunity to improve the effectiveness and decrease the negative impact of the technology with additional development effort.

4.7 Technology Evaluation

4.7.1 Detect and Extinguish Surface Cooking Fires: Fusible Link or Temperature Sensor for Fire Detection

We have combined two technology classes (1 and 2) into one evaluation because of the similarities of the two approaches.

Description/Overview

As described in Section 4.2, this technology is a fully automated fire detection and extinguishing system for surface cooking fires. The system includes a fire extinguishing cylinder assembly that is located above or to the side of the ventilation hood, and extinguishing agent nozzles located under the hood. There are two approaches to detect the presence of a fire. In one option, a fusible link melts at sustained temperatures of 289 to 370°F above ambient. This is a mechanical system that acts against a spring-loaded trigger for the fire extinguishing agent. An alternative detection approach is a temperature sensor. This approach requires an electronic controller to activate the extinguisher. In either case, the extinguishing agent is most generally a potassium-based wet-chemical, specifically formulated to extinguish grease fires. Sealed in the cylinder, the agent is good for 12 years.

When a discharge occurs, the system will cut the supply of gas with an electronic solenoid cut-off valve. Pressing a reset button on the solenoid valve restores gas flow. If the range needed to be moved for this process, it may need to be repositioned by a service technician to ensure the proper use of the anti-tip system. With an electric range, the system will cut the power to the range. Resetting the circuit breaker in the home's electrical panel restores power.

The cylinders are rechargeable. In case of a discharge, the homeowner would bring the cylinder to a local fire-protection equipment dealer or possibly the local fire station.

Cylinders that are installed in a residential application need to be hydro-statically tested every 12 years. Batteries for the electronics may need to be changes annually. If the system is installed in any sort of public building, it usually needs to be checked once a year by the local fire marshal or approved fire inspector.

Technology Development Status

Products or technologies triggered by a fusible link include:

- the Ansul Systems, manufactured by Reliable Fire Equipment, typically used in commercial cooking applications,
- The Safety Gourmet, manufactured by PEMALL, marketed for residential applications.
- The Guardian Systems (I) manufactured by 21st Century International Fire Equipment and Services Corporation, with over 45,000 units installed (primarily in military housing)
- 6 US patents covering various elements of extinguishing agents, extinguishing configurations, actuators, and detectors.

Additional products were considered but eliminated from this category, including:
Stove Top Fire Stop (because it is not approved for use with deep fat frying.)
Fire Breaker Fuel Neutralizer (because no information was available about this product).

Products or technologies triggered by a non-optical temperature sensor include:

- The Guardian System (III) manufactured by 21st Century International Fire Equipment and Services Corporation, this is an electronic control version of the Guardian I system.
- Five US patents covering temperature sensor technologies and configurations,
- One Japanese patent covering a full detection and extinguishing system

Potential Impact of Technology on Product Performance and Consumer Behavior

This approach will have no effect on cooking processes, cooking time, consumer behavior, cooktop features, or cookware applicability. There is a low risk for false actuation of the system, and the system components add little added risk to the homeowner.

The fire extinguishing systems are sold to fire equipment installers. There is, therefore, a third party involved in installing and servicing the systems.

Potential Effectiveness of Technology to Mitigate Cooking Fires

The technology will cover almost any type of surface cooking fire, whether it is attended, unattended, cooking materials, other materials etc. The technology is applicable to both gas and electric ranges, although some additional components might be required in a gas range in order to allow for safe shut-off and re-start. There will be some situations in which hood installations are cumbersome, unsightly, or unacceptable. These installations include some percentage of island or peninsula locations, ranges with integral downdraft ventilation, and some installations with space constraints/cabinetry that does not allow for the installation of the fire extinguishing cylinder. These situations may represent approximately 10% of all range installations.

One significant issue with the technology is that, in its current configuration, it cannot guarantee fail-safe operation, as defined by the industry as inhibiting cooking function on the range if the safety system is not operating properly. There is no interconnect to ensure that the range is shut down if the pressure in the cylinders drops below a set level or if the extinguishing cylinder is not refilled. There is a pressure gauge on the cylinder to determine if the cylinder is operational. The electronics that control the system also have a self-diagnostic function that will flash an LED to let the user know that the system is operating correctly.

The homeowner is responsible for checking the pressure in the cylinders and having the units hydrostatically tested at appropriate intervals (recommended by the manufacturer for every 12 years). Some fire extinguishing manufacturers mail reminder cards to the homeowners at the appropriate intervals to have the systems checked. This approach has its limitations.

With regard to impact of the fire extinguishing system on the cooktop or on the safety system after actuation, these technologies are messy to clean-up. The fire extinguishing material goes all over the room, and there is significant effort required to recharge the system.

Development Needs and Issues

The primary development need for this technology is a means to ensure 'fail-safe' operation. This would mean that it would need to have some way to confirm that the tanks were charged and at the appropriate pressure. This implies that the system would need electronics and a self-diagnostic system.

Another issue relates to system life. The pressurized cylinders need periodic hydrostatic tests to ensure that they have no cracks or leaks. The pressure transducer integrated into the self-diagnostic might be sufficient to provide insurance of system integrity, but this would have to be confirmed. In addition, the system requires annual battery change. This requirement would be unacceptable to the industry since a battery failure could result in a service call. In order for the system to meet industry standards for reliability, life, and safety, it probably would need to be wired into the home electrical service. The need for an electrical connection adds the drawback that gas ranges could not be used in the event of a power failure.

4.7.2 Prevent Unattended Cooking – Warning and Control
Motion sensor only (Tech Class 10)
Motion + Power sensor (Tech Class 12)
Warning Only, Motion Sensor only (Tech Class 14)

Description/Overview

These three approaches use a motion sensor to detect the presence of a person near an operating range. The systems use warnings or warnings and control to require the cooking process to be attended. These three related approaches will be evaluated as a set of technologies. Technology Class 10 uses a motion sensor to detect the presence of a person near the range; the lack of an attending person results in an alarm, followed by power modulation or shut-off if no one returns. Technology Class 12 uses a power level sensor in addition to a motion sensor so that the system is activated only if the heat input to the hobs is above a threshold level. The final Technology Class 14 is a warning system only. An alarm will sound if no one is detected near an operating range, but there is no control system to affect the power level.

These technologies are intended to work by changing consumer behavior. They will encourage or require the cook to be present near the range during the cooking process. In a way, this approach is similar to the way the automotive industry encourages the use of seatbelts. If we turn on a car and have not fastened our seat belt, a warning will sound. The warning bell is a reminder to follow safe behavior. These technologies are either exactly analogous to this approach (Tech Class 10, Warning Only), or they continue one further step. With the Warning and Control options, the power input to the range is either modulated or shut-off if the cook does not return to the range.

These technologies score highly in safety system effectiveness because they are intended to prevent a fire from igniting, are is applicable to most product classes, and can be made to be 'fail safe'. The basic operating assumption is that if a cook is attending the range, then the significant number of fires that are associated with unattended cooking can be prevented.

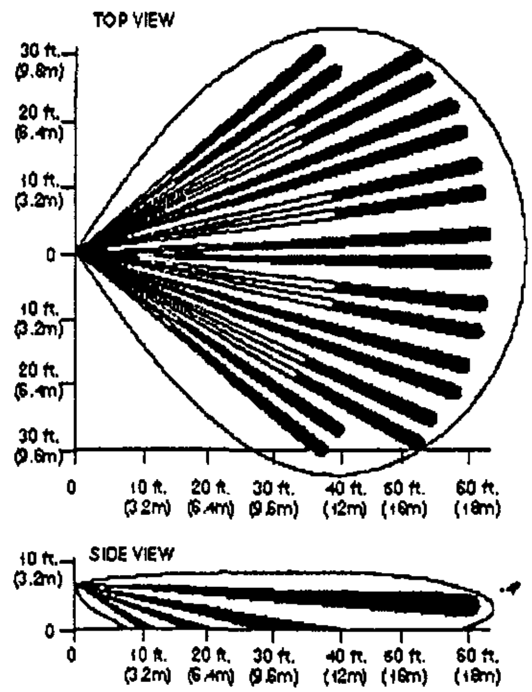
All these technologies involve the use of a motion sensor to detect the presence of a person near the range. A description of motion sensor technology is provided below.

Motion Detectors
Motion detectors can be grouped into two categories, passive and active. Passive sensors do not emit any energy, they only look or listen for changes to the environment. Active sensors emit a form of energy and then look for an echo of the transmitted energy.

Passive Sensors
Passive sensors use an infrared detector to detect differences in heat. These systems are often referred to as PIR (passive infrared). The systems usually consist of a plastic lens that focuses the IR energy onto one or more solid-state IR sensors. The lens allows the unit to have a wide field of view (FOV) and still only one or two sensing elements. The sensors are tuned to be most sensitive to the surface temperature of the human body,

around 93 °F, or as radiated infrared energy, between 9 and 10 micrometers. Thus, most sensors are most sensitive in the range of 8 to 12 micrometers. When these sensors detect a change of energy in the form of heat they become excited and output a signal. The microprocessor connected to the sensor then determines if the change occurred quickly enough and was large enough to trigger the system.

The sensors have a 5-year warranty. Since the sensor has no moving parts there is nothing that could be considered a wear item. Typical units have been in use for 10 – 15 yeas with no problems. The lens is the only exposed part that need to be inspected. If grease were to build up on its surface, it could reduce the transmittance of the IR source. The typical range of PIR sensors can be seen on the figure below.



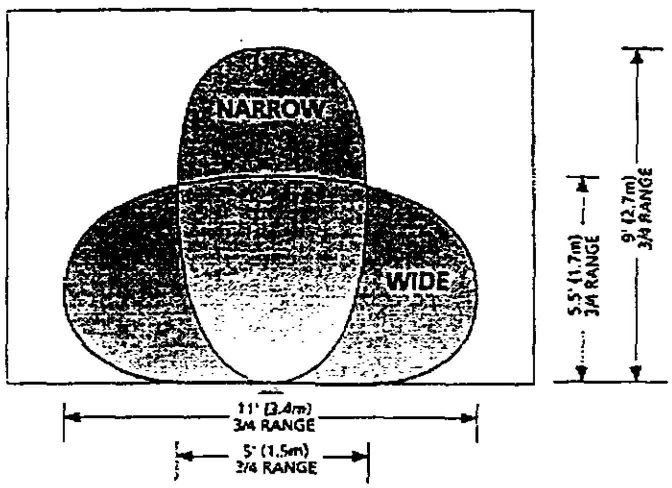
The field of view of the passive sensors is not very wide. As shown in the diagram, it could be possible to be standing a few feet from the range but be out of the view of the sensor.

Active Sensors

Active sensors use microwave, ultrasonic, or radio frequency energy to detect motion. In their simplest form, they are miniature radar systems. They emit a pulse of energy for a few milliseconds and then spend the next few milliseconds listening for its return. This process repeats several hundred times a second. When there is a moving target in the field of view (FOV) of the detector, the echo returned to the receiver will differ from the no-motion echo. A rapid enough change in the echo signifies detected motion. The microwave systems use a frequency within the K-band, 24.05 GHz – 24.25 GHz.

Ultrasonic systems use a frequency in the 40 kHz - 50 kHz range. The radio frequency systems operate at 6.5 Ghz. Like IR systems, ultrasonic systems also can be affected by the build-up of a layer of grease or oil on the sensor surface, but the higher operating frequencies of the microwave and RF detectors mean their signals are not significantly affected by the presence of grease on the surface of the device. More sophisticated systems also use the Doppler effect to measure the change in frequency in the return pulse. This method increases the sensitivity of the system.

The systems generally have a wide and narrow user selectable FOV setting. Rotating the antenna configures the selectable FOV for narrow or wide. The maximum range of the unit is determined by the power of the transmitter. The typical ranges and FOV of active systems can be seen below. Typical units have a 5-year warranty. Aside from the mechanical relays in the unit, the electronics package can last at least 10 years.



Technology Development Status

Systems that would prevent unattended cooking though warning and control using a motion sensor only are covered in 4 US patents.

There is one Japanese patent that refers to the use of a motion detector plus one additional input (either power level or heat sensor) to control heat input to the cooktop.

The warning only system is a concept. There are no patents for this approach.

We are not aware of any commercial products using these safety systems.

Motion detectors alone are common components in home security systems and automatic door openers.

Potential Impact of Technology on Product Performance and Consumer Behavior

This approach will have a significant effect on consumer behavior. We anticipate that a significant number of range users currently leave the kitchen during certain cooking functions, such as boiling water in a kettle, simmering sauces, simmering stews or soups, canning, or bringing a pot of water to a boil. The warning and control system (motion sensor only) requires attendance whenever the cooktop is operating, or the system modulates the heat input to the pot. The warning only system (motion sensor only) provides a reminder to attend to the cooking, but there is little consequence if the warning is not heeded (like the warning bell in a car to fasten the seat belt). The warning and control system that uses a power level sensor as well as the motion sensor would allow some low power input functions, such as simmering sauces, to proceed unattended.

If the user does attend to the cooking process, there would be no impact on cooking time. If, however, the user does not attend to the warnings, and the system modulates or shuts-off the heat input to the range, cooking times will obviously extend. None of these approaches would affect other cooktop features or cookware applicability. There is minimal system maintenance required.

The motion detector could be applied to any type of product. It would not add any installation requirement or significantly impact service to the cooking unit. However, there are some current limitations regarding applying a power level sensor to gas units. We know of no existing system that would provide an accurate power level sensor for gas-fired units. The development of such a sensor would be straight forward, but would take an effort.

Product life may be an issue in the use of motion sensors and their associated electronics. As indicated above, the motion sensors have a five-year warranty, but typically last 10 or more in the field. These motion sensors are in many homes now as part of security systems. However, there is no data that suggests that the motion detectors can provide a 20-year product life with a safety factor of 2. There is no obvious reason that the motion sensor electronics should have a shorter life than the electronic controls currently in cooking appliances, but this potential for life would need to be tested.

Potential Effectiveness of Technology to Mitigate Cooking Fires

If all the unattended cooking fires could have been avoided by having a person attending to the range, these technologies would eliminate between 65 and 70% of all surface cooking fires. Unlike a fire extinguishing approach, these systems are intended to prevent a fire from starting. The fire would be avoided rather than extinguished.

In the systems defined by the referenced patents, the operation of the safety system could be verified manually, but not automatically. A self-check could potentially be built into the electronics, however. The technology as envisioned would be 'fail-safe', because the range would not operate without the circuit in place and operating.

One significant issue with the motion sensor technology is that, in its current configuration, there is potential for false actuation. For example, a large pet or child could trigger the motion sensor. The range operation would be enabled even if no one were attending to the cooking process.

Development Needs and Issues

The primary development need for this technology would be to obtain some consumer feedback on the acceptability of the general approach. This technology is intended to change consumer behavior. It is important to understand how consumers would respond to this requirement. Would a warning be effective or would it be ignored? Would consumers be significantly hindered by the inability to leave the room for extended periods of time during certain cooking processes? Would people develop approaches to 'trick' the systems? The industry will not accept any system that could bypass the operation of the safety system.

Beyond this broad consumer issue, there are questions of sensor and electronics reliability and life that need to be confirmed. Finally, an approach to detecting the power level setting on a gas range would need to be developed. We can envision a number of simple approaches to detecting knob position. The technical approaches could be similar to the ignition switches currently on gas ranges and cooktops. In this case, the knob position may need to be calibrated to the nominal heat input to the burner.

Overall, the engineering issues are straightforward to address. The consumer issues are much less clear.

4.7.3 Prevent Unattended Cooking -- Warning and Control Power level sensor + timer (Tech Class 13)

Description/Overview

A simple timer and power level sensor could achieve the same objective as motion sensor coupled with a power level sensor. In the configuration of Technology Class 13, a timer would sound a warning at pre-determined intervals (potentially related to power input level). The cook would need to press a manual re-set button to indicate his/her presence near the range. With the timer, the unit would provide an alarm even if the cook were nearby. Some range users could perceive this requirement as a nuisance.

As with the previous three technologies, the timer and power level sensor is intended to have an impact on consumer behavior. It will require the cook to be present near the range during the cooking process. If the cook does not activate a re-set button, the power input to the range is either modulated or shut-off.

This system scores highly in safety system effectiveness because is intended to prevent a fire from igniting, is applicable to most product classes, and can be made to be 'fail safe'. The basic assumption here is that attended cooking will reduce surface cooking fires.

Technology Development Status

There is one US and one Japanese patent that describe the combination of a timer and a power level sensor to require a user to stay close to an operating range.

We are not aware of any commercial products using this system.

Potential Impact of Technology on Product Performance and Consumer Behavior

This approach will have a significant effect on consumer behavior for the same reasons outlined in Section 4.7.2. The level of behavior modification required would depend on the timer interval settings for the various power levels. These timer intervals would need to be defined in a way that balanced safety and operational considerations at each power level. Short timer intervals may be necessary at high power levels to prevent overheating of small volumes of material, but this would require frequent resetting of the timer by the cook. Further analysis of tests characterizing ignition times of various foods or amounts of oil (such as the study by the AHAM cooking fires working group in 1986), would be needed to develop suitable timer interval settings. The impact of the system on cooking product performance is minimal, for the same reasons as described in Section 4.7.2.

A simple timer and power level sensor may have longer life than the motion sensor, but this system would have more consumer impact. With the timer, the unit would provide an alarm even if the range user were nearby. The user would need to actuate a re-set button on a regular basis.

Potential Effectiveness of Technology to Mitigate Cooking Fires

If all the unattended cooking fires could have been avoided by having a user attend to the range, these technologies would eliminate between 65 and 70% of all surface cooking fires. Unlike a fire extinguishing approach, these systems are intended to prevent a fire from starting. The fire would be avoided rather than extinguished.

In the systems defined by the body of patents, the operation of the safety system can be verified manually, but not automatically. The technology would 'fail-safe', because the range would not operate without the circuit in place and operating. It is possible that an electro-mechanical implementation could be designed (i.e. no electronic control board required). However, with electronics, a self-check could potentially be built into the system.

This system is unlikely to be 'tricked' or result in false actuation.

Development Needs and Issues

As with the motion detector systems, the primary development need for this technology would be to obtain some consumer feedback on the acceptability of the general approach. This technology would be implemented to change consumer behavior. It is important to understand how consumers would respond to this requirement.
Technically, the approach would be straightforward to implement.

4.7.4 Prevent food ignition in the pan – electrical signal processing, auto-activation – T sensor contacts pot

Description/Overview

These systems work on the basis of limiting the temperature at the bottom of the pan so that the ignition temperature of the pan contents is never reached. This process is automatic and requires no intervention from the user. There are two critical aspects of the technology: 1) the pan contact temperature sensor; and 2) the algorithms used to differentiated standard cooking conditions from pre-ignition conditions.

Technology Development Status

Two prototype systems exist, both developed on behalf of the CPSC. One is for an electric cooktop, the other for a gas cooktop.

- CPSC gas system: This measures temperature using a spring loaded thermocouple, partly shielded from the flame, which makes contact with the pan base slightly to one side of the burner. When the thermocouple reading reaches 590°F, the burner switches to a low setting. When the temperature drops below 590°F again, the burner switches back to its original firing rate (previously set using the knob on the range).

- CPSC electric system: This uses three thermocouples, spaced roughly equally around a circle, about 2 inches from the center of the electric ring. The thermocouples, which are spring-loaded, poke up between the gaps in the element and need to be carefully positioned so as not to contact the element. The control algorithm uses only the maximum of the three temperature readings. When this reaches 330°C (626°F), the element starts to cycle on and off (1 sec on, 6 sec off). If the temperature reaches above 360°C (680°F) for more than 2 seconds, the element shuts off completely.

In addition, spring-loaded, pan contact temperature sensors are common on 'gas tables': i.e. two-burner, gas-fired, countertop cooktop units sold in Japan. (The controls on the Japanese units incorporate a mode switch to select the appropriate algorithm, for frying, boiling, etc.)

Potential Impact of Technology on Product Performance and Consumer Behavior

This technology should not require changes to consumer behavior, but it could impact cooking processes and/or cooking time. Ideally, as described in Section 4.4.2, there is a significant gap between the pan temperature associated with pre-ignition conditions, and the pan temperatures required for standard cooking processes. If the pan contact sensor is well insulated from the burner or electric element, and if it has good contact with the bottom of the pan, it will reflect the actual pan bottom temperature and can be used in straightforward way in a cooktop controller. The engineering implementation of the pan contact sensor will strongly affect the efficacy of this approach. If the contact sensor does not contact the pan well, or if it is not well shielded or insulated from the burner itself, the sensor output would not accurately reflect the pan bottom temperature. If the sensor indicates a temperature higher than the actual pan bottom temperature, the controller would cause the element or burner to modulate prematurely, thus increasing cooking time or affecting a cooking process. There is much work that would need to be done to develop a reliable and durable pan contact sensor that has the performance characteristics needed for a controller that does not impact cooking time or cooking quality.

The effectiveness of the system depends on good contact between the pot and the sensor. Pan type and quality will affect the accuracy of the pan bottom temperature measurement. We anticipate that a system could be made to be compatible with most pan types. However, we expect that cooking times for glass or ceramic cookware could be extended because of the larger thermal gradient in those materials.

Reliability and life are significant issues. The gas tables with spring-loaded temperature sensors have been selling in Japan for 10 years. Two companies provided general data on sensor life. Rinnai has indicated that the average life of the sensors is expected to be five years. The also indicated that the product improvement cycle is short and the manufacturer keeps spare parts in stock for about five years. Paloma informed us that the average life of the sensor is expected to be eight years.

This life would probably not be acceptable to the US market that expects 15 – 20 year life from range components. Designing a pan-contact sensor that can meet the reliability and durability specifications outlined in Section 4.4.6 will be a significant challenge.

The industry has had experience many years ago with pan contact temperature sensors used in mechanical control circuits that were intended to provide fine temperature control to the cooking process. As we understand from discussions with appliance manufacturers and controls suppliers, the most frequent failures modes associated with the old 'Burner with a Brain' or 'Thermal-Eye' products included:

- The system would respond differently when an aluminum pot was used vs. a cast iron pot.
- Gas turndown was insufficient to meet the lowest temperature requirements.
- Electric elements of the time had high thermal inertia.
- There was inconsistent contact area between the pot and resistance coils.
- The sensing element was under constant abuse.

The first three issues are not as relevant for this safety application because fine temperature control is not required for the pre-ignition controller. The last two considerations, which are reliability and durability issues, are still relevant and would need to be addressed for this approach to be commercialized. The system must operate in a difficult environment in which grease or dirt can become baked onto the sensor. The system would need to operate under these conditions.

Potential Effectiveness of Technology to Mitigate Cooking Fires

This approach has the potential to address up to 75% of surface cooking fires. There has been some discussion about the statistics that indicate that cooking materials are an ignition factor in 72-77% of surface cooking fires. The question was posed whether the cooking materials that ignite are potentially *outside* of the pot, i.e. in the burner well or in the cooktop rough-in box. It has been hypothesized that a safety system that controlled pan temperature would not affect the ignition of oil or grease that had accumulated around and in the cooktop itself.

We conducted some very preliminary tests to investigate this hypothesis. We measured cooktop temperatures around the burner bowl, rough-in box, and cooktop surface during standard cooking functions and during conditions in which pan contents reached pre-ignition temperatures. We did not find any cooktop surface temperatures (in the burner bowl, under the burner, in the rough-in box etc.) that neared *flash* point of oils when the pan was at pre-ignition temperatures. We strongly agree that grease and oil around the cooktop would exacerbate a fire.

This approach is potentially applicable to gas units and open coil electric units. The Japanese units that use a pan contact sensor are generally open burners, with a hole in the center of the burner for the sensor. Obviously a different configuration would be needed for a sealed gas burner.

The implementation of this control approach in electric smoothtops is not currently feasible. The temperature below the glass ceramic cannot be used to indicate pan temperature accurately. Control suppliers are reluctant to provide additional information about the potential for the current pan detection sensors to be used as pot temperature sensors. It appears that the thermal inertia in the glass ceramic is too great for the sensor to provide a reasonable indication of pan temperature.

There are two additional important issues for 'effectiveness' that would need to be addressed. One is the potential for the system missing a pre-ignition condition due to the sensor being dirty or damaged. The second issues is designing a way for the system to 'fail safe.' It is not obvious how to implement a self-check that would prevent the range from operating if the sensor was not reading pan temperatures accurately.

Development needs and issues

Currently, the prototype systems do not meet all the requirements for commercial implementation.

The system used in the gas cooktop was the more successful. The algorithm used appeared to successfully limit pan bottom temperature indefinitely to below the oil ignition temperature, did not require any action from the user, and did not appear to adversely affect cooking. However it was not robust and would be easily damaged in the field. The current implementation was excessively noisy.

The electric system did succeed in preventing ignition in our tests, but the system was less satisfactory. Both boiling water and searing steak were adversely affected. In addition, the sensors could be easily damaged. The problem with the prototype is that the temperature sensors appear to be sensing as much of the element temperature as the pan temperature.

In both cases, the algorithm used was, in principle, valid for the task (although this would need to be confirmed for all cooking functions). However, extensive testing would be required to ensure that the exact parameters chosen (temperature thresholds, cycling times, reduced heat input rates etc.) were suitable for the widest range of cooktops, pan types and cooking functions.

In sum, the sensor design would have to be improved significantly, so that the pan bottom temperature measurements were more accurate and the sensor was much more robust. Some self-check or self-calibration could be needed to implement a fail-safe system.

Given the product development cycles in the industry, this effort probably would require a minimum of 2-3 years of development time and significant investment by both the appliance manufacturers and their vendors.

If this were successful, the resulting system would have a high probability of preventing most surface cooking fires without requiring modification of consumer behavior or affecting cooktop function.

4.8 Results Summary

This section summarizes our evaluation regarding the technical, practical and manufacturing feasibility of the selected technologies to address surface cooking fires. All the technologies reviewed in detail have the potential to mitigate a significant percentage of surface cooking fires. Their commercial feasibility varies by technology.

Detect and Extinguish Surface Cooking Fires, Fusible Link or Temperature Sensor for Fire Detection

There are commercially available systems that detect and extinguish surface cooking fires. They currently do not meet all the industry requirements for technical feasibility because they are not configured to 'fail safe'. However, the sensing and electronics necessary to detect the pressure in the extinguishing agent cylinders and to interconnect the system to the range is technically possible with a focused development effort.

There are some practical issues to resolve regarding high volume commercialization of this type of technology. These systems are currently manufactured, distributed, installed and serviced through 'third-parties' to the appliance industry. The appliance business and the fire extinguishing business are currently very different businesses, with different requirements for installers and service personnel. In order to commercialize a mass-produced solution for the industry, significant coordination could be required.

These systems are currently manufactured in volumes of a few to ten thousand units per year. The technical, manufacturing, installation, service, and support infrastructure would need to be greatly expanded to provide products for the entire range market.

Prevent Unattended Cooking, Warning and Control – Motion Sensors

This technology is very early in the development process. At this stage, however, the general approach appears to be technically feasible. The reliability and life of the motion sensors and electronics would need to be addressed. A power level sensor for a gas burner would need to be developed. It is expected, however, that a focused, two-year development effort could produce a manufacturable product.

The practical aspects of this solution, however, are not so straight forward. This approach requires significant changes to consumer behavior. It is not clear that the requirements imposed by the systems as described would be acceptable to consumers. The system that couples a motion sensor with a power level sensor may mitigate some of the consumer resistance. It would be critical to conduct some consumer feedback work to understand their response. The safe cooking products will enter the market only if consumers purchase them; the products must be acceptable to the consumers.

Prevent Unattended Cooking – Warning and Control, Power Level Sensor and Timer

The feasibility of this approach is very similar to the motion sensor systems. The approach is technically feasible and could be manufactured using conventional techniques. The consumer response to the approach needs to be tested.

Prevent Food Ignition in the Pan – Contact Temperature Sensor

The current sensor approach is not technically feasible due to lack of reliability and durability. The Japanese sensor technology is a reasonable starting point for a development effort, but it is currently applied only to open-burner gas systems, a product class that is rapidly decreasing in US market share. In addition, some type of self-check algorithm would need to be developed to implement a fail-safe system.

The benefit of this approach is that it would impose significantly less constraint on consumer behavior than any of the systems that require attended cooking. It is potentially less problematic to implement than the fire extinguishing systems. However, it would take an extensive development effort of 2-3 years to develop the contact temperature sensor and robust cooking algorithms.

This approach is currently not feasible for glass ceramic (smoothtop) cooktops. In these systems, pot temperature need to be inferred from glass temperature or from the temperature in the region below the glass. The variations in contact between pots and the glass ceramic surface make the temperature difference between the glass and the pot too variable. The thermal inertia of the glass ceramic is a problem as well to have appropriate response time to avoid a potential cooking fire.